Vol. XVI, Part V October, 1946

THE
INDIAN JOURNAL
OF
AGRICULTURAL SCIENCE

Issued under the authority

of

The Imperial Council of Agricultural Research

Annual subscription
Rs. 15 or 23*s*. 6*d*.

Price per part
Rs. 3 or 5*s*.

Published by the Manager of Publications, Delhi
Printed by the Government of India Press, Calcutta, India.
1947

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Vol. XVI, Part V

(October, 1946)

The Editiorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal

Original articles—

ORIGINAL ARTICLES

COMPARATIVE STUDIES ON INDIAN SOILS

VIII. COMPARATIVE NITRIFYING CAPACITIES OF SOILS

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(Received for publication on 21 March 1944)

(With one text-figure)

COMPLEMENTAL to the mechanical and chemical analyses of soil samples collected in connection with the 'Comparative Studies on Indian Soils' the microbiological analysis was deemed necessary as the activities of soil micro-organisms variously affect the availability of the nutrient elements present in the soil. The project of a thorough study not being convenient one of the important processes brought about by soil microflora was studied.

The need for such study originated for several reasons. It would firstly show whether a particular soil contained the requisite organisms for the transformation of organic nitrogen present in or added to the soil to the available form ; secondly whether the nature of the soil is congenial to the activity of such organisms ; thirdly workers in foreign countries [Brown, 1912 ; Gainey, 1917 ; Burgess, 1918 and Waksman, 1923] have arrived at a conclusion that there is a direct correlation between fertility and nitrification. Nitrification experiments with soil samples collected from the Punjab Field Experiment Area, Pusa, with different manurial treatments corroborated it (*Report of the Imperial Agricultural Bacteriologist* 1931-32, 148). It was, therefore, expected that a study like this would throw some light on the fertility status of the soil obtained from the stations.

There are various ways of testing a soil for its nitrifying capacity [Waksman 1923]. Some workers prefer liquid media into which a known quantity of soil sample is seeded and the transformation of either the ammonia or nitrite to the nitrate stage is noted. There are others who use the soil itself and study the oxidation of inorganic chemicals like ammonium chloride or sulphate or fermentation of protein nitrogen supplied in the form of fish manure, blood meal and oil cakes in doses to supply 30 mg. nitrogen per 100 gm. of soil within a fixed period. Following the work of Stevens and Withers [1909] workers have agreed that biological processes are best studied in the soil medium itself.

The use of fish manure and blood meal have not attracted much attention in India. Ammonium sulphate was not used because of its acidic nature. If used it would have reacted differently with the soil samples having a wide range of pH and led to an erroneous picture of the nitrifying capacity of the soils under study. Oilcakes are widely used for manurial purposes, so mustard cake was used as the source of nitrogen throughout the course of study. The cake was freed from oil and added to supply 30 mg. nitrogen per 100 gm. of soil.

As soil samples from variously manured plots would lead to a wrong measure of the nitrifying capacity [Joshi, 1928] samples were generally collected in February and March 1937 from unmanured cultivated plots to depth of 0-9 in. These samples were air dried away from sun and saturation capacities determined. Workers at Pusa [Joshi, 1920 and Walton, 1928] adopted $\frac{1}{3}$ saturation as optimum for nitrification so in the present work moisture was maintained at $\frac{1}{3}$ saturation ; weekly addition of water was made to make up for any loss and the samples mixed thoroughly before each estimation. The samples were stored in wide mouthed bottles provided with cover of paste board and wax cloth to minimize loss due to evaporation. The bottles were incubated at 30°C. the temperature most suitable for soil organisms [Hutchinson and Milligan, 1910-11].

Periodical determinations of ammoniacal, nitrite and nitrate nitrogen were made for eight weeks. Nitrate and nitrite were estimated by phenol disulphonic acid and Greiss Illosvay methods and ammonia was determined by acidification with hydrochloric acid and distillation with magnesia. The data are given in the appendix along with pH figures. There were 57 stations and as more than one sample was obtained from some of the stations the number of samples examined totalled to 92.

In general most of the soils nitrified to the extent of 50 per cent and above of the added nitrogen. Soil samples from Assam, Bengal with the exception of the sample from Rangpur, soil from Ranchi in Bihar, Chandkhuri in the Central Provinces and from Padegaon, Surat and Belgaum in Bombay show low nitrifying capacity, nitrifying even less than 25 per cent of the added nitrogeon. These

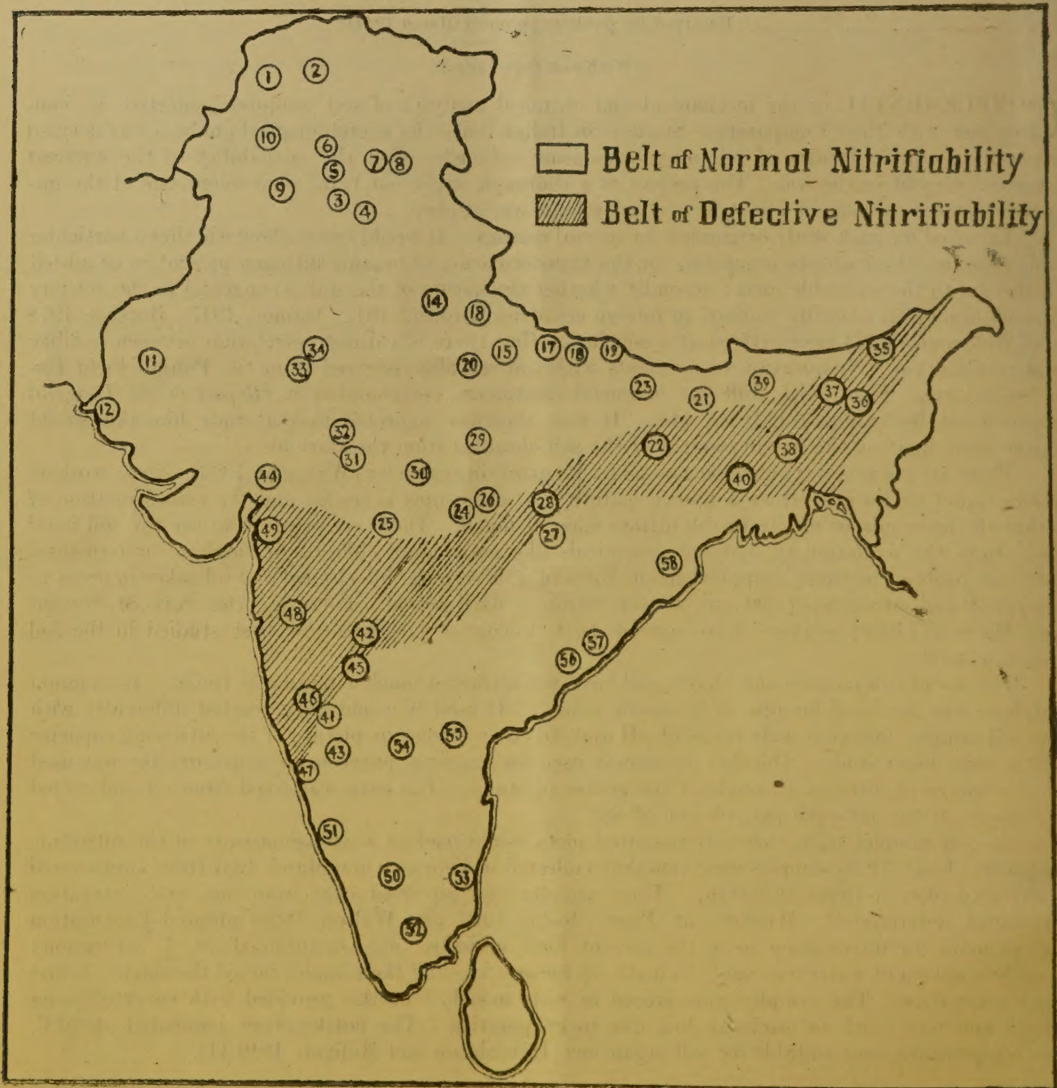

FIG. 1. Map of India showing the belts of normal and defective nitrifiability

soils with low nitrifying capacity occur in places lying in a narrow belt which runs from east to west across the middle of India and include practically all soil types. The soils from this defective nitrifying belt are under separate study and form the subject of another paper. It may, however, be stated here that most of the soils from the defective nitrification belt show normal nitrification if the moisture content is raised to $\frac{1}{2}$ saturation instead of $\frac{1}{3}$ as is usually employed. This suggests that to maintain these soils in proper status of fertility more moisture is needed.

The soils from the Punjab fell between *p*H 7·0 and 8·2 except Gurdaspur and Kangra, the *p*H of which were 6·9 and 6·2. All the soil samples nitrified well.

The *p*H of the soils from the United Provinces ranged between 6·6 and 7·9 and was suitable for proper nitrification.

In Bihar, the Kanke (Ranchi) samples had *p*H at 6·0 and 6·1 which adversely affected nitrification. Patna soil had *p*H 6·9 and so it nitrified to the extent of 30 per cent. Sabour soils nitrified well with *p*H 7·1 and 7·2.

C. P. soils having *p*H between 6·4 and 7·1 nitrified well except Chandkhuri which had its *p*H 6·4.

The *p*H of Central India soil ranged between 7·5-7·6 and so nitrification was above 70 per cent in these soils.

Ajmere and Merwara soils nitrified between 68 and 73 per cent and the *p*H ranged from 7·1 to 8·6.

Assam soils were acidic with *p*H between 5·1 and 5·8 ; evidently there was little or no nitrification. In Bengal, Dacca soil nitrified only 12 per cent because the *p*H of its soil was 5·1. Although Rangpur and Chinsura had the same *p*H, Rangpur sample nitrified up to 59 per cent whereas the Chinsura sample nitrified only 20 per cent.

Sholapur, Bijapur black, Belgaum, Padegaon and Surat soil samples from the Bombay Presidency were curious in their inability to nitrify with *p*H between 6·4 and 8·2. Kumta soil (0-4 in.) with *p*H 6·0 nitrified to the extent of 59 per cent.

The *p*H of Madras soils varied from 5·5 to 8·2 and moderate nitrification of Taliparamba and Koilpatti soils might be due to their *p*H being towards acid side. From the above data it may be concluded that nitrifying efficiency of soils was affected by *p*H below 6·0 although there were instances where *p*H values near about 6·4 had also adversely affected nitrification.

Summary

The comparative nitrifying capacities of soils from 57 stations all over India were studied with moisture equivalent to $\frac{1}{3}$ saturation and oil cake.

A narrow belt comprising of all soil types was found. Soil samples from stations within this belt did not nitrify above 25 per cent of the added nitrogen with above mentioned moisture but improved with $\frac{1}{2}$ saturation.

*p*H 6·0 and below adversely affected nitrification.

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APPENDIX

Nitrifying power of surface soils

Serial No.	Province	Sample	Depth	Saturation per cent	Milligrams N per 100 gms. soil																		Maximum nitrification per cent and week	pH
					Initial			1			2			4			6			8 weeks				
					NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3		
1	U.P.	Aligarh—																						
		Canal Irrigated . .	0-9"	39·0	2·52	0·078	0·6	8·4	1·069	2·1	6·72	0·019	7·2	3·36	*nil*	15·6	3·36	trace	21·0	2·52	0·019	18·0	68 VI	7·4
2		Unirrigated .	,,	37·8	2·52	0·024	0·45	10·08	1·166	0·9	*nil*	0·078	8·4	2·52	*nil*	15·6	4·20	,,	21·0	3·36	0·039	19·2	68 VI	7·4
3		Well Irrigated .	,,	38·0	1·68	0·024	0·45	10·08	1·264	1·05	4·20	0·078	9·0	2·52	*nil*	16·8	3·36	,,	21·0	1·68	0·078	19·2	68 VI	7·3
		Cawnpore—																						
4		Dumat . .	,,	35·0	1·68	0·099	0·3	9·24	1·166	0·9	4·20	0·097	9·6	1·68	*nil*	16·8	0·84	,,	21·0	0·84	0·039	19·2	68 VI	8·4
5		Matiyar . .	,,	40·8	1·68	0·058	0·45	8·4	0·058	0·75	*nil*	0·028	4·8	1·68	*nil*	15·0	1·68	,,	16·5	1·68	0·078	15·6	54 VI	6·9
6		Usar . .	,,	47·6	2·52	0·136	2·40	6·72	0·486	0·37	2·52	1·215	1·80	1·26	0·049	10·80	0·93	0·233	12·00	2·80	0·17	13·50	37·0 VIII	..
		Orai—																						
7		Mar . .	,,	44·2	2·52	0·058	0·45	9·24	0·107	0·37	10·08	0·253	0·60	7·14	0·097	2·55	3·36	0·097	9·00	1·68	0·078	15·00	48·5 VIII	7·4
8		Parwa . .	,,	42·2	2·52	0·049	0·45	10·92	0·049	0·45	9·24	0·350	3·60	1·26	0·015	15·00	0·84	0·029	16·20	1·68	0·039	16·50	53·5 VIII	..
9		Kabar . .	,,	42·1	2·52	0·049	0·52	10·08	0·024	0·27	10·08	0·097	2·40	2·94	0·015	16·80	0·84	0·029	17·40	1·68	0·029	18·00	58·3 VIII	7·9
10		Rankar . .	,,	37·0	2·52	0·039	0·45	9·24	0·027	0·30	8·40	0·078	1·20	7·14	0·778	4·20	1·26	0·024	15·60	0·84	0·017	15·75	51·0 VIII	7·9
11	Bihar	Sabour—																						
		non-paddy . .	,,	42·3	1·68	0·039	0·45	9·24	1·361	0 90	5·04	0·039	12·00	2·52	0·034	15·00	1·26	0·019	16·50	2·52	0·007	16·50	53·5 VI	7·1
12		paddy . .	,,	53·2	2·94	0·107	0·45	6·72	0·053	2·25	4·20	traces	14·40	2·52	0·034	18·00	1·26	0·034	18·00	1·68	0·024	18·00	58·5 IV	7·2
		Kanke—																						
13		Upland . .	0-5"	32·8	2·94	0·010	0·45	12·60	0·010	0·15	15·12	*nil*	traces	16·80	0·017	1·35	10·92	0·015	6·60	10·08	0·005	8·40	26·5/VIII	6·0
14		Upland . .	5-9"	31·0	2·52	0·002	0·45	13·44	0·005	0·15	15·12	*nil*	traces	16·80	0·007	0·60	16·80	0·034	1·20	12·60	0·002	6·00	18·5 VIII	
15		Valley . .	0-9"	35·8	2·52	0·010	0·45	12·60	0·002	0·15	14·28	*nil*	traces	15·96	0·005	0·75	15·96	0·019	1·50	11·76	0·002	7·20	22·5 VIII	6·1
16		Patna, heavy .	,,	46·1	*nil*	*nil*	0·6	5·88	0·126	0·45	5·04	0·156	1·2	4·2	0·078	3·0	5·88	0·078	6·0	5·04	traces	9·0	28 VIII	6·9
17	U.P.	Gorakhpur— Bangar . .	0-5"	35·2	1·26	*nil*	0·45	14·28	0·486	1·20	8·4	0·058	9·0	6·7	traces	15·6	3 36	*nil*	19·2	2·52	*nil*	21·0	68 VIII	6·6
18		Bangar . .	5-9"	38·4	2·94	*nil*	0·6	12·6	0·097	0·6	10·92	traces	0·6	8·4	,,	12·0	*nil*	*nil*	16·8	3·36	*nil*	22·8	74 VIII	6·6
		Padrauna—																						
19		Bhat lowland .	0-9"	52·0	1·68	*nil*	0·9	7·56	0·116	1·5	4·20	0·039	6·0	5·04	,,	[illegible]	5·04	0·078	15·6	5·88	traces	21·6	69 VIII	7·2
20		Bhat upland .	,,	38·5	1·68	*nil*	0·45	7·56	0·777	1·2	5·04	0·156	12·0	6·72	,,	[illegible]·2	5·88	0·078	15·6	9·24	,,	19·2	63 VIII	7·4
21		Fyzabad, loamy .	,,	40·1	*nil*	*nil*	0·45	11·76	0·038	0·15	10·08	1·56	1·8	4·2	,,	12·0	5·04	*nil*	14·4	0·84	*nil*	28·0	92 VIII	6·6

		Shahjahanpur—																						
22		loam	,,	37·8	nil	nil	0·75	4·20	1·069	1·5	5·04	0·039	12·0	4·2	,,	13·2	4·20	nil	18·0	2·52	nil	36·0	118 VIII	6·6
23		heavy loam	,,	48·6	0·48	0·019	0·30	9·24	0·030	0·15	11·78	trace	1·8	9·24	,,	6·0	4·20	trace	18·0	1·68	nil	36·0	119 VIII	..
24	Bengal	Dacca	0-9″	38·6	2·52	0·048	0·75	10·08	0·039	0·9	15·96	,,	1·2	18·48	,,	1·5	22·68	0·078	3·6	19·32	nil	4·2	11 VIII	5·1
25		Chinsura	,,	3·0	3·36	0·039	0·60	0·84	0·097	0·9	9·24	0·078	2·7	9·24	0·155	2·7	9·24	trace	1·5	10·92	traces	6·6	20 VIII	6·4
26		Rangpur	,,	48·0	3·36	0·015	0·37	10·92	0·078	1·80	7·56	0·024	6·60	1·68	0·022	14·40	0·84	0·049	18·00	0·84	0·022	18·00	58·8 VI	6·4
27	Assam	Karimganj	,,	55·6	2·52	0·049	0·37	14·28	0·049	0·60	18·48	0·053	0·45	19·32	0·117	0·45	21·84	0·097	0·75	20·16	0·097	1·95	5·3 VIII	5·8
28		Sylhet	,,	39·2	3·36	0·010	0·45	14·28	0·005	0·60	20·16	0·015	0·45	21·84	0·024	0·30	24·36	0·024	0·30	23·52	0·044	0·67	0·6 VIII	5·1
		Jorhat—																						
29		Upland	,,	45·4	5·04	0·005	0·75	17·64	0·034	1·95	24·36	0·039	1·05	26·88	0·039	1·35	28·56	0·034	1·50	29·40	0·022	2·10	4·5 VIII	5·2
30		Rice plot	,,	35·2	3·36	0·005	0·37	14·28	0·007	0·60	91·32	0·077	0·45	20·15	0·022	0·45	24·36	0·024	0·45	24·36	0·015	0·45	0·8 I	5·1
31	C.P.	Nagpur	,,	50·1	1·68	0·019	trace	9·24	0·039	0·6	12·6	0·078	0·9	10·92	0·039	3·0	12·6	0·194	3·0	3·36	0·194	18·0	60 VIII	7·9
32		Akola	,,	57·1	1·68	0·097	,,	10·92	0·019	2·4	10·08	0·116	3·6	5·88	0·039	3·2	2·52	0·039	21·6	1·68	trace	20·4	72 VI	7·9
33		Waraseoni	,,	37·0	2·52	0·019	0·3	10·08	0·039	1·8	12·6	traces	2·4	7·56	nil	9·6	0·84	trace	19·2	1·68	trace	18·0	63 VI	6·4
		Labhandi—																						
34		Kanohar	,,	43·5	1·68	0·049	trace	10·08	0·019	1·5	9·24	0·155	2·4	6·72	0·155	9·6	4·20	0·039	19·2	0·84	traces	21·6	72 VIII	7·6
35		Matas	,,	42·0	2·52	0·039	,,	15·12	0·019	1·2	14·28	0·039	1·5	9·24	0·019	10·2	2·52	0·039	18·6	nil	,,	24·0	80 VIII	6·5
36		Chandkhuri	,,	34·9	1·68	0·039	,,	10·92	0·39	trace	15·12	0·039	1·2	15·12	trace	2·4	12·6	trace	3·6	7·56	,,	5·4	18 VIII	6·4
37		Kheri—Adhartal	,,	43·5	1·68	0·039	,,	10·08	0·039	,,	11·76	0·078	1·2	8·4	0·019	5·4	4·20	0·019	8·4	nil	0·019	16·8	56 VIII	6·7
38		Powerkhera	,,	42·4	1·68	0·039	,,	10·08	0·058	,,	10·92	trace	0·9	7·56	0·583	6·0	4·20	0·194	12·0	nil	traces	18·0	60 VIII	7·7
39	C.I.	Indore—																						
		Irrigated	,,	42·1	5·04	0·078	,,	8·40	0·155	0·9	8·4	0·155	3·6	11·76	0·155	15·6	7·56	0·078	18·0	0·84	0·039	21·6	72 VIII	7·5
40		Unirrigated	,,	47·1	2·52	0·078	1·2	4·20	0·583	6·0	5·04	0·078	14·4	0·84	0·039	26·4	0·84	0·039	25·2	nil	0·039	25·2	80 IV	7·5
		Kharua—																						
41		Unirrigated	,,	45·1	5·04	0·024	0·45	5·88	0·097	0·75	6·72	0·097	3·00	0·00	0·039	18·00	0·00	0·019	22·50	0·00	0·024	22·50	73·5 VI	7·6
42		Irrigated	,,	44·1	2·10	0·039	0·45	14·28	0·486	2·10	8·40	0·214	10·80	1·68	0·024	21·00	1·68	0·044	22·50	1·68	0·029	22·50	73·5 VI	..
43	Ajmere Merwara	Makrera—																						
		Unirrigated	,,	28·0	3·36	0·007	0·37	7·56	2·041	2·25	2·52	0·024	14·40	1·68	0·012	18·00	1·68	0·012	22·50	1·68	0·015	22·50	73·8 VI	8·0
44		Irrigated	,,	31·8	2·52	0·010	0·45	8·40	2·722	2·85	1·68	0·049	19·50	1·68	0·012	18·00	1·68	0·024	21·00	1·68	0·022	21·00	68·5 VI	7·1
		Tabiji—																						
45		Unirrigated	0-9″	19·7	2·52	0·005	0·45	12·60	2·138	0·75	7·56	1·944	5·10	5·04	0·010	15·60	2·52	0·007	19·50	1·68	0·010	21·00	68·5 VIII	7·9
46		Irrigated	,,	27·0	2·52	0·044	0·30	8·40	4·277	0·97	10·08	4·277	5·70	2·52	0·024	21·00	1·68	0·078	21·00	1·68	0·024	21·00	69·0 IV	8·6
47	N.W.F.P.	Peshawar	,,	37·0	3·36	0·019	0·30	15·96	0·032	0·22	3·78	1·515	1·35	3·36	0·012	18·00	2·52	0·022	18·00	2·52	0·015	19·50	64 VIII	7·8
48		Haripur Hazara	,,	44·8	4·20	0·058	0·30	14·28	0·535	3·30	5·46	0·583	15·00	4·20	0·034	19·50	3·36	0·087	19·50	3·36	0·039	21·00	69 VIII	7·3
49	Punjab	Lahore	,,	34·0	3·36	0·012	0·30	15·12	0·017	0·37	13·86	0·583	3·15	4·20	0·017	18·00	3·36	0·029	18·00	3·36	0·017	19·50	64 VIII	7·6
50		Ferozepur	,,	42·2	4·20	0·010	0·30	16·80	0·486	0·67	9·66	1·515	6·90	8·40	0·010	16·50	7·56	0·039	16·50	8·40	0·024	16·50	54 IV	7·7

APPENDIX—*contd.*

Nitrifying power of surface soils—*contd.*

Serial No.	Province	Sample	Depth	Saturation per cent	Milligrams N per 100 gms. soil																		Maximum nitrification per cent and week	pH
					Initial			1			2			4			6			8 weeks				
					NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3	NH_3	NO_2	NO_3		
1																								
	Punjab—*contd.*																							
51		Kalashah Kaku .	0-6"	31·4	1·68	traces	0·15	13·44	0·194	1·8	12·6	1·944	3·0	0·84	0·039	14·4	4·20	0·078	24·0	5·04	0·078	24·0	79·5 VI	8·1
52		Kalashah Kaku .	6-9"	36·5	3·92	,,	0·15	12·60	traces	0·6	15·12	trace	*nil*	7·56	1·944	1·2	4·20	0·078	15·6	2·52	0·039	19·2	63·5 VIII	8.1
53		Gujranwalla .	0-9"	32·9	0·84	,,	0·15	13·44	,,	1·8	15·12	0·194	4·8	1·68	0·039	18·0	0·84	0·039	21·6	2·52	0·039	18·0	71·5 VI	7·6
54		Gurdaspur . .	,,	34·5	2·54	,,	0·15	6·72	0·078	1·5	8·4	trace	6·0	0·84	trace	14·4	2·52	trace	16·8	2·52	0·019	19·2	63·5 VIII	6·9
55		Kangra . .	,,	35·4	1·68	trace	0·15	18·48	trace	1·2	16·8	0·039	2·4	6·72	0·039	10·8	7·56	trace	15·6	8·40	*nil*	15·6	51·5 VI	6·2
56		Lyallpur . .	,,	31·8	3·36	0·015	0·22	15·96	0·039	0·30	15·12	0·972	0·45	2·52	2·13	16·50	2·52	0·079	19·50	1·68	0·019	19·50	64·3 VI	7·6
57		Mianwali . .	,,	22·6	2·52	0·015	0·22	15·12	0·194	0·45	7·56	0·680	9·00	1·68	0·022	19·50	1·68	0·019	19·50	1·68	0·019	19·50	64·3 IV	8·2
58	Sind	Sakrand—																						
		Sweet land .	,,	34·6	1·68	0·039	0·30	10·92	0·389	2·70	0·84	0·049	18·00	0·84	0·024	18·00	0·84	0·022	18·00	1·68	0·044	19·50	64VIII	7·9
59		(Salt land) .	,,	39·8	2·52	0·029	30·0	13·44	0·194	36·00	7·56	2·916	28·80	0·00	2·916	33·00	1·68	0·024	27·00	1·68	0·029	27·00	20·0 I	..
		Karachi—																						
60		Malir Farm .	,,	38·0	1·68	0·049	0·37	14·28	0·078	0·82	10·92	0·972	3·00	0·84	0·029	15·00	0·84	0·058	15·00	1·68	0·058	15·00	48·8 IV	..
61		Burn's Garden .	,,	37·7	0·84	0·0098	9·0	5·88	0·583	9·0	11·76	0·311	5·4	14·28	0·156	5·4	12·60	0·777	9·0	7·56	0·972	9·0	*nil*	7·9
62		Sewage Farm .	,,	29·1	0·84	trace	0·9	15·12	0·078	0·3	11·76	0·622	0·6	6·72	2·332	3·6	2·52	0·194	16·8	*nil*	trace	16·8	53·0 VI	8·1
63		Mirpurkhas . .	,,	47·3	1·68	0·039	0·45	12·60	0·155	0·9	12·60	0·155	9·0	1·68	0·097	21·6	1·68	0·019	21·6	*nil*	trace	21·6	70·5 IV	7·7
64	Madras	Coimbatore—																						
		Black . .	,,	44·7	1·68	0·0194	0·15	13·44	0·039	0·3	3·36	trace	1·2	7·56	1·166	8·4	2·52	0·109	24·0	0·84	trace	21·6	79·5 VI	8·2
65		Red . .	,,	36·2	0·84	0·0194	0·30	15·12	0·058	0·6	6·72	0·311	9·0	0·84	trace	19·2	2·52	trace	24·0	0·84	trace	21·6	79·0 VI	8·1
66		Red, Irrigated .	,,	34·5	0·84	0·0194	0·60	12·60	0·0972	0·3	2·52	3·888	2·40	1·68	0·019	14·4	2·52	trace	18·0	0·84	*nil*	20·4	66·0 VI	7·9
		Taliparamba—																						
67		Dry . .	,,	42·2	1·68	0·0972	0·90	16·80	trace	0·6	19·32	0·155	1·50	20·16	*nil*	2·4	19·32	*nil*	6·0	12·6	*nil*	9·6	29·0 VIII	6·0
68		Wet . .	,,	41·6	*nil*	0·1944	2·25	15·12	trace	2·1	16·80	0·0389	3·0	17·64	0·038	4·8	16·80	0·194	7·2	13·44	trace	9·6	24·5 VIII	5·5
		Koilpatti—																						
69		Black . .	,,	52·0	*nil*	0·0194	0·9	4·20	0·0972	0·3	7·56	0·058	1·8	6·72	0·038	2·4	4·20	0·155	12·0	*nil*	*nil*	18·0	57 VIII	8·1
70		Red . .	,,	36·0	0·84	trace	0·6	12·6	trace	0·3	12·60	0·0194	1·8	10·92	0·038	5·4	0·84	0·039	13·2	1·68	*nil*	9·6	42·0 VI	6·5
71		Aduturai . .	,,	41·2	*nil*	0·049	trace	4·20	0·078	1·5	5·88	trace	2·1	6·72	trace	4·8	3·36	trace	6·0	0·84	trace	15·6	52 VIII	6·6

72		Hagari	,,	44·0	1·68	0·019	trace	9·24	trace	1·2	10·08	*nil*	*nil*	7·56	0·038	1·8	4·20	3·110	7·8	2·52	trace	18·0	60 VIII	8·2
73		Nandyal	,,	44·2	1·68	0·049	trace	6·72	0·078	2·1	8·4	trace	4·2	4·20	0·583	12·0	0·84	trace	19·2	*nil*	trace	20·4	68 VIII	8·1
74		Samalkot	,,	47·0	*nil*	0·078	trace	6·72	0·389	2·1	6·72	0·194	3·0	7·56	0·039	6·0	1·68	trace	7·2	*nil*	trace	19·2	64 VIII	7·2
		Anakapalle—																						
75		Dry	,,	35·0	2·52	0·019	trace	9·24	1·944	9·0	2·52	trace	15·6	2·52	*nil*	25·2	1·68	trace	25·2	*nil*	trace	19·2	84 VI	7·1
76		Wet	,,	38·4	1·68	0·009	trace	11·76	0·039	1·8	9·24	trace	1·8	7·56	7·039	15·6	1·68	trace	24·0	*nil*	trace	19·2	80 VI	6·5
77		Berhampur	,,	24·7	0·84	0·019	0·30	11·76	1·166	0·60	7·56	2·333	4·50	1·68	0·019	16·50	0·00	0·015	16·50	*nil*	0·015	19·50	64 VIII	6·8
	Bombay	Bijapur—																						
78		Deep black	,,	48·8	2·52	0·019	0·30	10·08	0·024	0·30	11·76	0·058	0·37	10·92	0·097	0·45	10·08	0·117	0·45	7·56	0·194	0·75	1·5 VIII	8·2
79		Med. black	,,	48·2	2·52	0·024	0·30	10·08	0·058	0·30	8·40	0·117	0·45	10·08	0·350	1·20	6·72	0·194	6·60	0·84	0·019	18·00	59 VIII	8·1
80		Limy	,,	49·7	1·68	0·024	0·30	10·08	0·097	0·30	9·24	0·097	0·60	8·40	0·389	3·30	0·84	0·032	18·00	*nil*	0·015	21·00	69 VIII	7·9
		Kumta—																						
81		North Canara Karwar	,,	36·6	2·52	0·049	0·30	14·28	0·010	0·37	15·12	0·015	1·20	12·60	0·019	5·40	8·40	0·010	12·00	4·20	0·015	18·00	59 VIII	6·0
82		Disintegrated laterite	,,	40·6	0·84	0·005	0·22	11·76	0·005	0·22	11·76	0·005	0·22	12·60	0·010	0·37	12·60	0·005	0·37	12·60	0·005	0·52	1·0 VIII	6·3
83		Padegaon	,,	47·2	3·36	0·024	0·45	10·92	0·097	0·45	12·60	0·097	0·60	11·76	0·097	0·90	10·08	0·194	1·35	10·08	0·107	2·70	7·5 VIII	7·2
		Dharwar—																						
84		Cultivated	,,	53·0	2·52	0·204	0·30	12·60	0·117	0·60	6·72	0·058	1·35	3·36	0·078	4·80	2·52	0·034	10·80	*nil*	0·022	18·00	59 VIII	7·7
85		F.Y.M. series	,,	48·4	1·68	0·019	0·30	5·04	0·049	0·45	8·40	0·019	1·05	6·72	0·005	2·10	6·72	0·010	2·70	4·20	0·019	5·40	17 VIII	7·2
		Nadiad—																						
86		Lowland	,,	40·2	3·36	0·019	0·37	8·40	1·166	3·60	1·68	0·486	16·80	*nil*	0·039	18·00	0·84	0·039	18·00	*nil*	0·053	21·00	68·8 VIII	8·0
87		Highland	,,	30·1	2·52	0·015	0·37	10·08	0·339	2·40	1·68	0·078	15·00	*nil*	0·024	18·00	0·84	0·027	18·00	*nil*	0·044	19·50	63·8 VIII	7·7
		Sholapur—																						
88		Deep soil	,,	57·5	1·68	0·024	0·37	3·36	0·078	0·67	5·88	0·068	0·90	5·04	0·117	1·50	5·04	0·073	3·00	5·04	0·029	3·00	8·8 VI	7·4
89		Light Shallow	,,	37·3	2·52	0·019	0·37	6·72	0·039	0·37	8·40	0·019	0·67	7·56	0·136	4·20	3·36	0·036	12·00	3·36	0·015	15·00	48·8 VIII	7·7
90		Med. deep	,,	59·1	1·68	0·015	0·22	4·20	0·068	0·37	5·88	0·058	0·45	5·88	0·024	1·20	5·88	0·029	2·70	5·04	0·017	3·30	10·3 VIII	7·4
91		Surat	,,	45·1	1·68	0·012	0·22	5·04	0·029	0·30	6·72	0·029	0·37	6·72	0·033	0·75	8·40	0·024	1·20	8·40	0·015	1·20	3·3 VI	7·1
92		Belgaum, laterite	,,	43·2	0·84	0·012	0·22	5·04	0·029	0·52	7·56	0·022	0·75	7·56	0·207	2·70	8·40	0·022	5·40	8·40	0·012	5·40	7·3 VI	6·4

COMPARATIVE STUDIES ON INDIAN SOILS

IX. MINOR OR TRACE ELEMENT STATUS OF INDIAN SOILS—SPECTROSCOPIC ESTIMATION OF BORON CONTENTS

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(Received for publication on 30 March 1944)

THE importance of adequate supplies of the so called minor or trace elements in the soils is now established by workers in other countries and the need for the study of the problems of minor elements in India has been emphasized by Kharegat [1943]. Boron is the most important of these from the agricultural point of view. This may be seen from the fact that Bertrand *et al.* [1939] reported that the amount of boric acid used in Europe for one crop alone (sugar beet) mounted to a value of 18,000 tons in 1938. Therefore, the boron status of Indian soils has been under study and the results obtained for the boron content of soils by the spectro-chemical method are given in this paper.

The soils have been analysed spectroscopically by the methods of Gerlack and Sweitzer and also Mitchel [1940] (Methods of Analysis by Emission Spectrum of Adam Hilger). It consisted in foll-

TABLE I

Boron content of virgin surface soils

Number and name of the place from which the soil was taken		Boron content in p.p.m.
36	Karimganj	42·5
35	Jorhat	35·0
37	Sylhet	24·0
38	Dacca	52·5
39	Rangpur	80·0
40	Chinsura	15·0
22	Ranchi upland	34·0
33	Makrera	22·5
34	Tabiji	30·0
31	Indore	57·5
32	Kharua	40·0
24	Nagpur	30·0
25	Akola	27·5
27	Labhandi	27·5
28	Chandkhuri	40·0
51	Taliparamba	25·0
52	Koilpatti	15·0
54	Hagari	33·0
55	Nandyal	50·0
56	Samalkot	30·0
57	Anakapalli	15·0
50	Coimbatore	8·5
3	Lahore	57·5
9	Lyallpur	70·0
10	Mianwali	20·0
8	Kangra	45·0
7	Gurdaspur	57·5
12	Karachi	33·0
11	Sakrand	50·0
13	Mirpurkhas	7·0
19	Padrauna	70·0
18	Shajahanpur	45·0
	Average	37·2

owing the density of the boron line at 2497·73 A° keeping the other boron line itself at 2496·78 A° Fe line 2496·53 and the back ground as the variable internal standards. The accuracy of the results was ensured by printing one or two known standards on each plate and keeping the electrical and mechanical conditions as nearly constant as possible. The sample for arcing on the copper electrodes was taken after a one-gram sample of the soil is thoroughly mixed with 3 c.c. of tested nitric acid and evaporated on a water bath to the consistency of a solid paste. Duplicate determinations usually agreed within 5-10 per cent based on the quantities of boron present.

The surface first foot layer of the virgin and cultivated soils from different parts of India collected for the comparative studies on Indian soils have been analysed.

Results and discussion

The results for the virgin soils are given in Table I and those for the cultivated soils in Tables V and VI. Comparative figures for the soils of some other countries taken from published literature are given in Tables II and IV B.

Table II

Comparative data for different countries on the boron content of soils

Country	Range of values in parts per million	Average in p.p.m.	Source of information
1. *U.S.A.*	11.4—48.0	30.0	Whetstone, Robinson and Byers [1942]
(*a*) Half Bog, Ground water Podzol and muck soils	..	21.6	
(*b*) Podzol soils	..	21·2	
(*c*) Non calcic brown soils	..	11·7	
(*d*) Red and yellow podzolic soils	..	22·6	
(*e*) Red desert soils	..	11·4	
(*f*) Rendzina soils	..	..	
(*g*) Grey brown podzolic	..	43·9	
(*h*) Priarie, chestnut, chernozem and brown soils	..	35·3	
(*i*) Alluvial soils	..	48·0	
2. *Germany*			
(*a*) Granitic soils	2—3	..	Goldschmidt and Peters. Quoted by Whetstone, Robinson and Byers [1942]
(*b*) Marsh and red soils and those from shale	15—30	..	
3. *Tuscany*	20—100	..	Luchetti. Quoted by Whetstone, Robinson and Byers [1942]
4. *Florida*	100—500	..	Rogers and associates. Quoted by Whetstone, Robinson and Byers [1942]
5. *India*—			
Entire country	7—80	37·2	See Table I
87·5 per cent of the soils	15—57·5	36·7	

These figures show that the boron values for the Indian soils are quite comparable with those of the United States and show as much variation.

In order to gain some idea as to the nature of the soil boron, these values are considered in terms of the different ways of soil classification. The boron values on the basis of the usual colour and climatic classifications are given in Table III. From this it is seen that although this grouping is not homogeneous with respect of the boron values of different soils some rough indications are, however, revealed. The red and black soils have about the same average, being the lowest ; but this average increases steadily in the sequence—red-black, brown, grey and pink, and calcarious soils.

TABLE III

Boron p.p.m. in soil groups according to colour and climate

Climatic groups	Calcareous soils	Colour grouping of the soils				Average on climatic basis
		Red soils	Black soils	Brown soils	Grey pink soils	
Arid region soils	Sakrand =50				Mianwali =20·0	
		..	..	Lyallpur =70·0		
	Karachi =33				Mirpurkhas = 7·0	36·0
Semi-arid region soils	....	..	Akola =27·5	Tabiji =30·0	Lahore =57·5	
			Indore =57·5	Coimbatore = 8·5	Gurdaspur =57·5	34·5
			Kharua =40·0			
			Koilpatti =15·0	Anakapalli =15·0	Makrera =22·5	
			Hagari =33·0			
			Nandyal =50·0	Delhi =35·0		
Humid region soils	Padrauna =70	Ranchi =34	Nagpur =30·0	Shajahanpur =45·0	..	38·5
		Chand-khuri =40	Labhandi =27·5	—		
	Pusa =55		Samalkot =30·0			
			Chinsura =15·0			
Per-humid region soils	....	Tali-paramba =25	..	Dacca =52·5		
				Sylhet =24·0	Rangpur =80·0	43·4
				Karimganj =42·5		
				Jorhat =35·0		
				Kangra =45·0		
Average on colour basis	50·2	33·0	32·5	38·4	40·7	

In Tables IV A and IV B are presented the data on the basis of the probable regional surface geology of these soils, and this seems to divide the soils into more or less homogeneous groups with the exception of the alluvial soils, the average for each group showing generally a tendency to indicate a relationship with geological epochs or geological age. This is in accordance with the laboratory findings of Reeve, Prince and Bear [1944] that the soil boron is readily leached from the soil, as more ancient the soil is, the more is it expected to have undergone weathering and leaching. With regards the alluvial soils, the Indo-Gangetic and Brahmaputra alluvium have higher boron content than either the alluvium from the older deposits or the soils which are subject to greater leaching by virtue of their topography and climate. If so separated this group also becomes quite homogenous with regard to their boron values.

TABLE IV A

Boron content of soil groups on the basis of their regional surface geology

Geological group	Place	Boron in p.p.m.	Probable geological origin
1. *Ancient crystalline*	Ranchi	34·0	Upland-Bengal gneiss
	Coimbatore	8·5	Granitoids foliated by nephelene
	Taliparamba	25·0	Granitoids with some garnets
	Koilpatti	15·0	Granitoids and some kankar
	Hagari	33·0	Granitoids and Dharwars
	Anakapalli	15·0	Granitoids with some kondalites and garnets
	Average	21·75	
2. *Delhi system*	Delhi	35·5	Triassic Delhi and Aravalli biotite, lime stones and lime quartzites.
	Makrera	22·5	Gneissic and granites
	Tabiji	30·0	Gneissic and Seynites also
	Average	29·33	
3. *Cuddapah system etc.*	Labhandi	27·5	Shales, slates, quartzites and limestones
	Chandkhuri	40·0	Shales, slates, quartzites and limestones
	Nandyal	50·0	Shales
	Average	39·2	
4. *Trap*	Kharua	40·0	Malwa trap
	Akola	27·5	Augite-basalt
	Nagpur	30·0	Between gneiss, Deccan trap and Gondwana
	Indore	57·5	Malwa trap-augite basalt
	Average	38·8	
5. *Alluvium or recent deposits*	Karimganj	42·5	From sand stone and shales with ferrugenous minerals
	Dacca	52·5	Deposits of the Burhi Ganga river
	Rangpur	80·0	From the Darjeeling and Sikkim ranges
	Padrauna	70·0	Alluvium of the Gondak from the Siwaliks
	Shajahanpur	45·0	Ganges valley-deposits from the outer Himalayas and Siwaliks
	Lyalipur	70·0	River wash from slates, laterites and shales
	Lahore	57·5	From Jammu hills and shales and Siwaliks
	Kangra	45·0	Upper tertiary, sandstone with shales and Siwaliks
	Sakrand	50·0	From shales and sandstone
	Chinsura	15·0	Deposits of the river Bhagirathi
	Samalkot	30·0	Coastal alluvium from trap and Kondalites
	Jorhat	35·0	Gneissic in character-alluvium from stones, gravel, etc.
	Sylhet	24·0	Sandstones and shales-sample taken from hill side
	Mianwali	20·0	Gondwana, upper Siwaliks and lower Miocene
	Karachi	33·0	Sandstone and marine limestone
	Mirpurkhas	7·0	
	Average	42·3	

TABLE IV B

Boron content of soils grouped on the basis of the rock systems

Nature of rock	Places	Average boron content in p.p.m.	Source of information
Granites	Coimbatore, Taliparamba, Anakapalli, Koilpatti, Makrera and Tabiji	19·3	Table IVA
Igneous rocks	In U.S.A.	14·1	Whetstone, Robinson and Byers [1942]
Shales and lime stones	Chandkhuri and Nandyal	39·2	Table IVA
Shales	U.S.A.	35·7	Whetstone, Robinson and Byers [1942]
Lime stone	U.S.A.	42·0	Whetstone, Robinson and Byers [1942]
Angite-basalt	Akola and Indore	42·5	Table IVA
Alluvium	India	42·3	Table IVA
Alluvium	U.S.A.	48·0	Whetstone, Robinson and Byers [1942]

TABLE V

Effect of cultivation on boron content of soils

Name of the place from which the soils were taken	Boron in virgin soil in p.p.m.	Boron in cultivated soil in p.p.m.
Lahore	57·5	40·0
Kangra	45·0	35·0
Gurdaspur	57·5	55·0
Jorhat	35·0	30·0
Hagari	33·0	22·5
Nandyal	50·0	27·5
Samalkot	30·0	22·5
Anakapalli	15·0	9·0
Akola	27·5	10·0
Chandkhuri	40·0	18·5
Indore	57·5	25·0
Karachi—Malir Farm	33·0	90·0
Karachi—Sewage Farm	42·0	90·0
Karimganj	42·5	95·0
Sylhet	24·0	40·0
Sakrand	50·0	60·0
Mirpurkhas	7·0	10·0
Dacca	52·5	65·0
Chinsura	15·0	95·0
Padrauna	70·0	..
Shahjahanpur	45·0	60·0
Nagpur	30·0	35·0
Labhandi (Matasi)	35·0	40·0
Rangpur	80·0	80·0
Ferozeshapur	No sample	80·0
Kalakashi	..	70·0
Gujranwali	..	35·0
Pusa—North Punjab Field	..	55·0
Aligarh	..	47·5
Cawnpore	..	80·0
Orai	..	83·0
Sabour	..	66·0
Patna	..	50·0
Bishnupur	..	65·0
Fyzabad	..	80·0
Adurtirai	..	7·5
Berhampur	..	18·5
Delhi	..	35·0

In passing to consideration of the cultivated soils, it may, however, be recorded that conclusions on the probable zones of boron deficiency are not drawn although the values for these soils for the pH, the calcium carbonate contents and the ratios of the exchangeable Ca/K and other figures which have a bearing on the availability of soil boron are known. This is because in the present state of our knowledge of the availability of soil boron, soil analytical data are incomplete without a comparative study of the field survey for the boron deficiency symptoms using the turnip or the sunflower or other standard indicator plant. This is all the more so because cultural practices, for example, green manuring, are known to alter this availability [Reeve, Prince and Bear 1944].

So far the boron contents of virgin soils have been considered. It would be interesting to see the effect of cultivation and agricultural practices on the boron contents of the soils. It is obvious that data on the same soil cannot be obtained for virgin and cultivated conditions and recourse must be had to different soils from the same place and collected at the same time. Admittedly it is not valid to draw conclusions in regard to the effect of cultivation on the boron content of a given soil, but there is distinctly a tendency towards increase or decrease in the boron contents as the result of cultivation and cropping as can be seen from Table V.

As the result of cultivation some soils have shown a tendency to increase while some others to decrease in their boron contents. The reasons may lie in the differences due to irrigation waters and manurial treatments. In Tables VIA and VIB are given the comparative data for a few cultivated soils of known irrigational (as against rain fed ones) and manurial history.

TABLE VI A

Effect of irrigation

Name of the place	Boron content in unirrigated soils in p.p.m.	Boron content in irrigated soils in p.p.m.
Aligarh (under canal irrigation)	47·5	75·0
Aligarh (under well irrigation)	47·5	45·0
Anakapalli	48·5	9·5
Indore	25·0	32·5
Kharua	35·0	55·0
Makrera	18·5	29·5
Tabji	15·0	55·0

TABLE VI B

Effect of manuring-soils from permanent manurial plots—Pusa

Nature of the treatment	Boron content in p.p.m.
Soil from plot without any manure for 30 years	35·0
Soil continuously manured with oil cake only for 30 years	90·0
Ammonium sulphate super phosphate potassium sulphate only continuously for 30 years	95·0
Ammonium sulphate only for 30 years	47·0
Farmyard manure only for 30 years	55·0

Tables VI A and VI B show that irrigation water adds boron in areas which are rich in this element (Table IV) as the boron of the river bed is leached and passed on to irrigation water. On the other hand, areas like Anakapalli, which represents an area of one of the most ancient tracts, have already been fully leached and contribute little to irrigation water. The leaching action of this water on soil patches rich in boron is more than what it might add. Table VI B indicates that oil cakes or super plus potassium sulphate are the best manures for maintaining a high level of boron in the soil. Thus in addition to what is taken away by the crop, the nature of the irrigation water and the manurial treatment determine the difference in the boron values of a cultivated and virgin soil in the same locality.

Summary

1. The boron content of Indian soils is comparable with that of the soils of the United States.
2. The soil boron shows a definite tendency to decrease with the geological epoch or age of the rock from which the soil is derived.
3. The boron content of the cultivated soil differs considerably from that of the corresponding virgin soil and this is shown to be dependent amongst other things on the nature of irrigation water and the manurial treatment employed.

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COMPARATIVE STUDIES ON INDIAN SOILS

X. BORON AND MANGANESE CONTENT OF SOME INDIAN SOILS

By V. V. K. Sastry and B. Viswanath, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 30 March 1944)

It is now recognized that in addition to the so called major elements of plant nutrition which are required to be present in or supplied to the soil, certain other elements are essential in minute quantitites for the growth and development of higher plants. These elements which are required to be present in minute quantities or traces are, for the sake of convenience, called trace elements or minor elements. So far the essentiality of boron, copper, manganese and zinc is no longer open to dispute according to the latest review by Arnon [1943].

Methods and material

In the present communication certain soils have been examined by chemical methods for the boron and manganese content of Indian soils. It has become necessary to perfect and standardize methods of analysis for some of these elements existing in minute quantities in soils. Accordingly methods for the quantitative colorimetric determination of boron and manganese have been standardized and forms a separate communication by the authors [1944]. A brief outline of the methods and the results obtained for 20 soils are recorded below. The soils examined so far include surface and profile samples from both cultivated and virgin fields in the Provinces of Punjab, Sind and the experimental plots in Pusa (Bihar).

Preparation of soil solution. The soil (2 gm.) was fused with approximately five times its weight of anahydrous, sodium carbonate in a platinum basin and the melt dissolved in about 40 c.c. of 4 normal sulphuric acid. When all the melt had disintegrated, the solution was filtered into a 100 c.c. measuring flask and the filter and dish washed with double distilled water till the filtrate was

free from sulphate. The solution was then cooled and made up to 100 c.c. The residue on the filter was discarded if it was found to be white. a further extraction is necessary if found coloured. 25 c.c. aliquots were separately taken for the determination of boron and manganese.

Estimation of boron. The method employed was that developed by Smith [1935] using a 0·1 per cent solution of quinalizarin in 98·5 per cent sulphuric acid medium taking all the precautions mentioned by Oleon and De Turke [1940] with slight modifications in the experimental technique for the colourimetric comparison. The details of this method have been recorded in a recent communication by Sastry and Viswanath [1944].

Estimation of manganese. The method for determining this element colourimetrically consists in oxidizing the manganous salt into permanganate by the use of sodium or potassium periodate in strongly acid media according to the method developed by Willard and Greathouse [1917]. The permanganate so formed develops a pink colour which is estimated colourimetrically by comparing the colour with a blank solution containing all the reagents and taking the percentage light transmisability of the test solution compared to the blank from which the concentration of manganese can be directly read off from a standard curve prepared with permanganate solutions of known manganese contents. The details of the method and the experimental technique have been recorded elsewhere [Sastry and Viswanath, 1944]

Results

The results are recorded in Table I. All the figures were corrected to the nearest integer.

Table I

Boron and manganese content of Indian soils

Name	Depth	Boron in p.p.m.	Manganese in p.p.m.
Lahore	0—1 ft.	66	852
,,	0—9 in.	43	654
Lyallpur	0—1 ft.	25	681
Mianwali	0—1 ft.	22	716
Kangra	0—9 in.	62	487
,,	0—1 ft.	86	1634
Gurdaspur	0—9 in.	57	598
,,	0—1 ft.	68	1282
Ferozepur	0—9 in.	16	570
Kalashahkaka	0—6 in.	28	939
Gujranwala	0—9 in.	27	1613
Karachi—Burn's Garden	0—9 in.	29	1668
Karachi—Malir Farm	0—9 in.	29	375
Karachi	0—1 ft.	32	473
Karachi—Sewage Farm I	0—9 in.	31	424
Karachi	0—1 ft.	29	138
Pusa—Gourchi Field	0—8 in.	42	542
,, South Mysore Field	0—8 in.	46	641
,, North Pangarbi Field	8—23 in.	50	601
,, Original sample	0—8 in.[1]	39	711

A depth of 0—1 ft. for uncultivated and 0—8 in. or 0—9 in. for the cultivated soil were taken for the above study.

Conclusion

These results show that these soils contain enough manganese and boron in these soils and the agricultural problems in those areas therefore concern more their availability than with their presence or absence.

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COMPARATIVE STUDIES ON INDIAN SOILS

XI. PHOSPHATE FIXATION CAPACITIES OF SOILS

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(Received for publication on 30 March 1944)

(With one text-figure)

THE phosphate that is added to the soil can be held by it in one or more or all of four different ways and the mechanism of fixation is sought to be explained by chemical [Fraps, 1922; Teakle, 1928; Doughty, 1930; Scarseth, 1934; Scarseth and Tidmore, 1934; Metzgar, 1940], adsorption [Gordon, 1925; Mattson, 1927; Roszman, 1927; Ravikovitch, 1934; Megrorge, 1935] and absorption [Ford, 1932; Daris, 1934] theories. The absorption theory is further explained by electrokinetic, ionic and Werner's complex salt formation theories [Mattson, 1931; Ford, 1933; Tiulin, 1936]. Fixation can occur in one or more of the following ways: (1) The cations of the salts in the soil solution react with phosphate ions and form precipitates; (2) by mass action and double decomposition with relatively insoluble soil minerals insoluble phosphates may be formed; (3) by adsorption at the soil-solution interface; and (4) by absorption and formation of complex systems in one or more of the solid phases of the soil.

The capacity of a soil to fix phosphates, therefore, depends on the origin and the physical and chemical composition of the soil. A study of the relative phosphate fixing powers of soils is useful in distinguishing soil types as such and in relation to phosphate manuring. This is of particular importance in that field experiments with phosphate manuring have in a number of cases not given response to the extent expected even in soils considered to be deficient in phosphates by chemical analysis.

The purpose of the present investigation is to obtain some characteristics of phosphate fixing properties of Indian soils, to compare the values obtained for different types of soil, and to discuss the probable significance of the determinations carried out.

MATERIALS AND METHODS

Forty-two soil samples from unmanured fields of several experiment stations in different parts of India were taken to determine the phosphate fixing capacity.

For purposes of this study, the total fixation is measured under uniform conditions of (1) keeping the phosphate solution at a suitable strength, (2) the ratio of soil to solution, (3) time, and (4) temperature of interaction. A soil solution ratio of 1 to 10 is the one most commonly employed and this ratio was employed in the experiments reported in the paper.

The procedure adopted for comparing the fixing power of soils consisted in the agitation of the soils and phosphate solution for a period of 24 hours, using an electrically driven machanical shaker. This period has been found sufficient to establish equilibrium between the soil and the solution and to give reproducible results. The phosphate used was diammonium hydrogen phosphate $(NH_4)_2HPO_4$: 1·8591 gm. of the phosphate was dissolved in water sufficient to yield a solution containing 1 mg. P_2O_5 per c.c. of the solution and adjusted to pH 7·0 at this dilution.

For the fixation experiments, 10 gm. of air dry soil, passed through a 70 mesh sieve, were placed in a 250 c.c. glass stoppered measuring cylinder and 100 c.c. of the phosphate solution (1 c.c. = 1·0 mg. P_2O_5) were added. The mixture was shaken for 24 hours in a mechanical shaker, filtered through Whatman No. 2 filter paper, discarding the first few c.c. of the filtrate; 5 c.c. of the filtrate were used for the estimation of P_2O_5 according to the standard volumetric method of Pemberton Kilgore. The detailed results are given in the Appendix.

CLASSIFICATION OF INDIAN SOILS ON THE BASIS OF PHOSPHATE FIXING POWER

In Table I are given the amount of phosphate fixed in different soils, arranged in ascending order of fixation.

TABLE I

Phosphate fixing power of Indian soils

Soil	Percentage of P_2O_5 fixed	Soil	Percentage of P_2O_5 fixed
Tabiji	1·54	Kangra	3·59
Sylhet	5·14	Berhampur	7·41
Rangpur	8·64	Shahjahanpur	8·93
Gurdaspur	8·95	Jorhat	11·22
Makura	11·36	Lyallpur	12·04
Delhi	12·22	Mianwali	12·32
Ranchi	14·20	Dacca	15·00
Pusa	15·00	Karimgunj	17·39
Karachi	18·50	Lahore	19·14
Kumpta	22·53	Koilpatti	23·77
Peshawar	24·77	Anakapalli	25·00
Waraseoni	25·49	Taliparamba	26·67
Haripur Hazara	28·04	Mirpurkhas	29·61
Chandkhuri	33·95	Padegaon	48·77
Coimbatore	49·82	Kheri-Adhartal	55·07
Samalkot	56·49	Sakrand	58·01
Hagari	58·80	Powerkhera	61·74
Surat	62·23	Labhandi	64·46
Indore	66·86	Nandayal	68·68
Kharua	72·85	Nagpur	73·47
Padrauna	84·56	Akola	87·05

It is seen that there is a wide range of phosphate fixation and if the results are put on a map of India, three definite zones of low, medium and high fixing power can be differentiated as can be seen in Fig. 1. The soils in Northern India from the Punjab to Assam have a low fixing capacity, taking fixation up to 20 per cent of the added phosphate as low fixing power. Taking fixation between 20 and 60 per cent as medium fixing power the soils from the North-West Frontier Province, part of Sind, South Eastern part of the Central Provinces and Southern India including coastal regions in the east and the west, are of medium fixing capacity. The black soils of the Central Provinces and Berar, soils of some parts of Central India, Bombay Province and the Deccan fix above 60 per cent of the added phosphate.

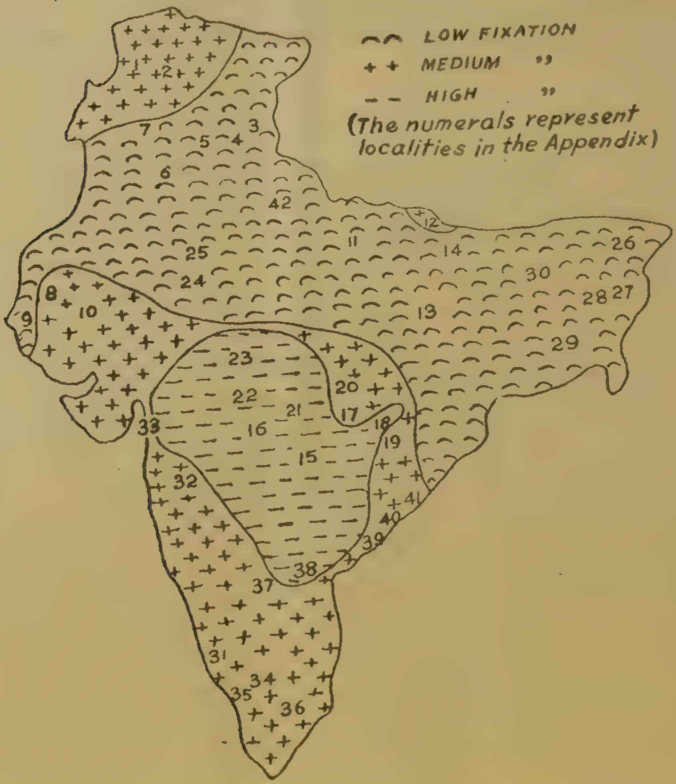

FIG. 1. Map of India showing classification of soils on the basis of phosphate-fixing capacity

On the basis of climatic grouping and colour grouping, described in an earlier paper of this series of comparative studies the actual amount of phosphate fixed is as below

TABLE II

Phosphate fixation in soils grouped in climatic or colour basis

Nature of soil	Number of soils	Average fixation in mg. of P_2O_5 per 100 gm. of soil
Arid	7	261·95±34·00
Semiarid	15	411·26±71·62
Humid	12	417·84±78·61
Perhumid	8	138·02±32·48
Black	11	619·59±14·78
Brown	8	218·61±78·12
Red	8	248·96±44·41
Pink and grey	15	237·86±35·74

Phosphate fixation in relation to physico-chemical properties of soils

To enable further examination of phosphate fixation in relation to physical and chemical composition and properties, the soils have been analysed and the relevant data for the soils are given in the Appendix. From these data, the relationship between pH, calcium carbonate content, clay content, exchange capacity, exchangeable bases and other values on the one hand and the phosphate fixation on the other, have been worked out.

Table III

Phosphate fixation and reaction of soils

pH range	Average pH	Average fixing power of mg. of P_2O_5 per 100 gm. of soil	Number of soils
3·5—4·5	3·94±0·05	122·4 ± 26·65	4
4·5—5·5	4·98±0·13	182·67± 42·65	6
5·5—6·5	5·99±0·19	225·47± 50·10	8
6·5—7·5	7·04±0·02	467·82± 19·09	18
7·5—8·5	8·08±0·02	416·61±100·90	6

Soils with acid reaction show low fixing power which increase as the pH value approaches 7. Beyond this value the fixing power tends to decline.

The relationship between clay content and phosphate fixation is close and direct as can be seen from Table IV. About 60 per cent clay and above a tendency for a fall in fixation is noticeable.

Table IV

Phosphate fixation and clay percentage in soil

Range of clay percentage	Average clay per cent	Fixation in mg. of P_2O_5 per 100 gm. of soil	Number of soils
0—15	9·45±0·67	191·28±56·40	17
15—30	19·91±0·81	237·98±45·30	9
30—45	36·85±3·10	373·91±77·90	4
45—60	54·46±1·70	687·30±35·30	7
60—75	66·75±3·50	600·35±46·30	4

In Tables V, VI and VII are given phosphate fixation in relation to total exchange capacity, exchangeable bases and exchangeable Ca. It will be noticed that fixation of phosphate increases with increase in total exchange capacity as well as increase in exchangeable base content and exchangeable calcium.

Table V

Phosphate fixation and total exchange capacity

Range of total exchange capacity in m.e.	Average total exchange capacity in m.e.	Average fixation by 100 gm. of soil (mg.)	No. of soils
0—15	8·08±0·51	198·53±20·19	24
15—30	17·62±1·02	238·67±33·80	3
30—45	37·24±0·25	564·54±35·10	3
45—60	52·86±1·79	618·88±30·20	11

TABLE VI

Phosphate fixation and total exchangeable bases

Range of total exchangeable bases in m.e.	Average total exchangeable bases in m.e.	Average fixation by 100 gm. of soil (mg.)	No. of soils
0—15	6·97±0·96	196·66±35·40	25
15—30	17·58±2·35	265·48±15·43	2
30—45	38·54±3·41	564·54±55·29	3
45—60	52·27±2·10	618·86±47·01	11

TABLE VII

Phosphate fixation and exchangeable calcium

Range of exchangeable calcium (m.e.)	Average exchangeable calcium (m.e.)	Average fixation by 100 gm. of soil (mg.)	No. of soils
0—16	5·16±0·57	198·86±32·61	27
16—32	29·21±3·05	598·67±49·58	4
32—48	41·39±1·26	610·72±53·69	10

The relationship between soil sesquioxides soluble in concentrated hydrochloric acid and phosphate fixation is presented in Tables VIII, IX and X. It will be seen that in conformity with the work of earlier workers, phosphate fixation increases with $Fe_2O_3 + Al_2O_3$ or Fe_2O_3 and decreases with silica/sesquioxide ratio.

TABLE VIII

Phosphate fixation and HC1 soluble $Fe_2O_3 + Al_2O_3$

Range of $Fe_2O_3+Al_2O_3$ per cent	Average of $Fe_2O_3+Al_2O_3$ per cent	Average fixation by 100 gm. of soil (mg.)	No. of soils
6—11	7·88±0·74	115·20±13·61	5
11—16	13·19±0·62	321·26±40·10	7
16—21	20·66±0·42	667·24±41·80	3

TABLE IX

Phosphate fixation and HC1 soluble Fe_2O_3

Range of Fe_2O_3	Average of Fe_2O_3 per cent	Average fixation by 100 gm. of soil (mg.)	No. of soils
2·25— 5·25	3·82±0·38	159·99±30·76	7
5·25 — 8·25	6·23±0·40	461·30±87·12	4
8·25—11·25	10·45±0·75	678·52±56·04	2

TABLE X

Phosphate fixation and SiO_2/R_2O_3 ratio

Range of ratio	Average ratio	Average fixation by 100 gm. of soil (gm.)	No. of soils
6—12	8·24±0·98	540·81±89·0	5
12—18	13·33±1·71	267·62±33·8	3
18—24	21·86±1·87	122·42±19·66	4

SUMMARY

On the basis of phosphate fixation Indian soils can be divided into three types. Those with low fixing capacity occur in Northern India from the Punjab to Assam. Soils of North-West Frontier Province, part of Sind, South Eastern part of the Central Provinces and Southern India, including coastal regions in the east and the west, are of medium fixing capacity. The black soils of the Central Provinces and Berar, soils of some parts of Central India, Bombay and the Deccan have got high fixing capacity. On the climatic basis, maximum fixation occur in soils of semi-arid and humid areas, on colour basis black soils fix most phosphates.

Fixation of phosphate is maximum at a pH about 7·0. It increases with the clay content, total exchange capacity, exchangeable bases and exchangeable calcium. It also increases with HCl soluble sesquioxides, and Fe_2O_3 but decreases with HCl soluble silica sesquioxide ratio. This is in conformity with the observations of earlier workers.

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Appendix

Statement of data on the soils used for the study of phosphate fixing capacity

Locality	Fixing power by 100 gm. of soil in mg.	*p*H	Clay percentage	Total exchange capacity m.e.	Total exchangeable bases m.e.	Exchangeable capacity m.e.	SiO_2 percentage	Fe_2O_3 percentage	Al_2O_3 percentage
Peshawar	247·70	6·70	11·90	6·85	5·08	4·65	63·50	[illegible]	15·25
Haripur Hazara	280·92	6·79	21·16	15·37	16·16	8·95	..	..	..
Lahore	191·40	6·87	17·66	9·90	9·20	7·70	..	..	..
Gurdaspur	89·53	5·82	11·58	7·05	6·58	5·45	89·53	3·49	3·90
Kangra	35·96	5·08	11·55	12·80	11·48	10·25	76·77	6·36	9·53
Lyallpur	120·40	6·97	9·89	7·10	6·53	5·55	84·97	2·50	1·81
Miannwali	123·29	7·64	13·58	5·56	5·22	3·10	..	..	..
Sakrand	580·16	6·82	9·37	9·35	8·62	6·50	..	..	..
Karachi	185·63	7·47	6·57	17·90	11·63	10·35	..	..	..
Mirpurkhas	296·16	7·50	16·21	8·17	11·31	6·25	72·5	4·88	7·20
Shahjahanpur	89·39	6·26	18·58	7·8	5·19	4·25	..	..	..
Padrauna	845·69	7·05	9·78	10·05	8·36	7·3	..	..	..
Ranchi	142·01	5·10	42·5[illegible]	10·00	8·61	5·75	..	..	..
Pusa (P. Field)	157·44	6·87	5·62	3·23	3·09	1·70	60·5	2·77	3·58
Nagpur	734·71	7·42	59·55	57·14	57·11	44·15	68·71	11·25	9·39
Akola	870·54	7·35	57·74	49·7	54·09	36·95	..	..	..
Waraseoni	255·49	5·66	21·67	8·57	7·19	5·44	..	..	..
Labhandi	644·66	6·78	60·07	40·71	41·86	31·84	69·7	7·6	13·8
Chandkhuri	339·57	5·40	18·12	6·85	6·48	2·50	..	..	..
Kheri-Adhartal	550·72	6·14	49·35	38·72	41·97	34·92	..	..	..
Powerkhera	617·40	6·91	57·50	48·86	48·86	41·78	..	..	..
Indore	668·65	6·77	65·40	48·57	53·75	44·60	..	..	..
Kharua	728·54	7·11	52·76	45·00	45·13	41·19	..	..	..
Makrera	113·61	6·08	8·36	9·79	8·97	4·60	..	..	..
Tabiji	15·44	7·70	5·04	6·28	6·06	3·00	..	..	..
Jorhat	114·22	3·63	6·80	1·85	3·26	0·05	72·2	6·4	9·4
Karimganj	173·94	4·08	20·95	10·96	10·11	4·55	..	..	..
Sylhet	51·45	3·91	11·69	9·14	2·81	1·09	..	..	..
Dacca	150·03	3·85	19·93	7·75	5·19	3·10	..	..	..
Rangpur	86·44	5·15	6·41	10·43	5·05	2·52	82·12	4·39	6·25
Kumta	225·35	4·66				..		..	..
Padegeon	487·75	8·71	74·75	67·14	69·8	48·00		..	..
Surat	622·34	6·88	47·10	48·56	51·78	40·82	67·50	9·66	10·28
Coimbatore	498·25	7·98	31·67	32·30	31·80	21·10	80·[illegible]	5·18	7·50
Taliparamba	266·72	4·51	29·59	9·20	7·87	1·70	53·8	..	..
Koilpatti	237·70	5·99	62·9	57·40	59·64	44·0	74·06	12·51	
Hagari	588·08	8·64	43·95	51·5	49·73	37·6	70·76	5·62	7·16
Nandyal	686·86	7·80	57·29	50·0	49·06	31·6	..	..	..
Samalkot	564·92	6·91	24·88	49·5	48·2	32·0	..		..
Anakapalli	250·05	5·72	9·48	19·6	20·0	12·4	..	..	
Berhampur	74·09	6·53	12·84	4·29	5·52	2·92	..	..	..
Delhi	120·25	6·29	10·33	9·3	10·09	7·6	81·25	3·59	4·51

INFLUENCE OF LIME ON SOIL POTASH

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(Received for publication on 20 September 1945)

THE behaviour of native potash in soil on addition of lime is highly controversial and gives rise to a number of theories. The literature abounds in conflicting views, the earlier investigations lend the view that liming tends to liberate potash. This view is not, however, corroborated by later investigations. In this connection mention may be made of Guthrie and Cohen [1907], Lipman and Gericke [1918], Gaither [1910], Wheeler [1910], Ames and Simon [1924], Brown and MacIntire [1911], Fraps [1916]. Their general conclusion is that the effect of lime on the liberation of potash is not at all marked if there is any liberation at all. Further evidence of the non-interfering action of lime on native potash is adduced by the Lysimeter studies of MacIntire and his associates [1930]. While the investigations of Bradly [1910], Jenny and Shade [1934] show that lime liberates potash from the soil, their conclusion is based on laboratory observations. Bradfield [1924] attaches considerable importance on soil reaction on potash liberation by lime.

Views also differ widely with regard to the effect of lime on the assimilation of potash by plant. Ehrenberg [1919] noticed a decrease in potash assimilation on the addition of lime and magnesia to the soil. Such a retarding action of lime on potash assimilation was also recorded by several other workers of which Loehwing [1925], Bledsoe [1929], Fonder [1929], etc. deserve special mention. It has also been shown by some that lime has got neither a positive nor a negative influence on the assimilation of potash by plants. Gunther [1926], Jenny and Ayrus [1939], Van Italie [1938], Albrecht and Schroeder [1942] etc., are among the important workers on this subject.

The obscure and conflicting nature of the action of lime on the liberation or otherwise of native potash led the present author to undertake the present investigation with a view to clarify some of the contradictory observations. Peech and Bradfield [1943] in a recent investigation laid emphasis on the presence of neutral salts and on the initial degree of base saturation of the soil. The absence of neutral salts in the soil will invariably result in the liberation of potash from the soil when lime is added to the latter. Evidence will be adduced here to show that the discrepancy, though minor, in the result recorded by different workers, is due to the lack of proper agreement in the experimental details.

It will be noticed that in the investigations referred to, no attempt was made to study the changes in the potash content of the soil from the very moment after the addition of lime periodically up to a considerable length of time. In some cases the potash content was determined immediately after the addition of lime and in some the same was determined after a lapse of time. It was, therefore, quite possible that there was disagreement regarding the behaviour of added lime, since lime does liberate potash and at the same time fixes it up. As it will be seen later on that the immediate action of lime is to liberate potash which again passes out of the solution either as an insuloble compound or as a constituent of the soil complex. Therefore, unless the reaction is studied from the beginning periodically for a considerable time, such discrepancy is bound to occur. In this experiment, therefore, the immediate action of lime on soil and its subsequent behaviour up to a period of four months was studied.

Before starting the experiment it was thought desirable to find out a suitable experimental condition with regard to the method of extraction. It was found that the extraction of the soluble potash by shaking with water was much better than the extraction by leaching with water. The soil water ratio and the time of shaking, therefore, play an important role in the extraction of soluble potash from the soil. In order to determine these two factors separate experiments were carried out.

Soil (400 gm.) were shaken with different quantities of water in the shaker for 12 hours and potash estimated in the extracts. The relevant data are submitted below.

of the different bases present in exchangeable form shows that the soil is mainly saturated with calcium. The quantity of other exchangeable bases is very low (Table V). Hence the high pH of this may primarily be ascribed to calcium saturation. The low potash content in exchangeable form shows that almost all the potash has already been replaced and further addition of lime has no effect on the potash concentration in the solution.

TABLE V

Exchangeable bases in Rajshahi soil

CaO	3·04 per cent
MgO	0·62 per cent
K_2O	0·08 per cent

It becomes apparent from the foregoing that the action of lime on the soil potash mainly depends on the soil reaction and the lime can exert its liberating action on soil potash only in a limited pH range, i.e. between pH 6 and pH 7. It may be noted that in the case of the Dacca soil the soluble potash increases with the increase in the amount of lime up to pH 7·05 and further increase in lime so as to make the system alkaline, has no appreciable effect on soil potash. This is quite in conformity with the contradictory results recorded by different investigators.

The question now arises as to what is the exact mechanism of the reaction. There are two ways by which the liberated potash can disappear from the solution : (1) by the formation of an insoluble compound, and (2) by the re-entrance of the potash into the soil complex in exchangeable form. The formation of an insoluble compound will preclude the possibility of extracting it by dilute acids. On the other hand, if the liberated potash re-enters the soil complex, it will be possible to extract it by any method in vogue for the determination of exchangeable bases. Attempt was, therefore, made to extract the fixed potash by William's method both from the fresh and the stored soil samples and to compare the potash figures obtained by shaking with water alone.

Twenty-five grams of soil mixed with 0·075 gm. of lime were shaken up with 100 c.c. of water for 24 hours. The whole was then transferred to a filter paper and washed with water (total 1000 c.c.) to determine the water-soluble potash. The exchangeable potash remaining in the complex was then determined by leaching the washed soil with N/2 acetic acid.

The water soluble potash and the exchangeable potash in the soil mixed with lime and kept saturated with water for a course of time were similarly determined in quadruplicate. The experimental results are given in Table VI.

TABLE VI

K_2O in mg. per 100 gm. of soil

	Water soluble potash	Potash in the soil complex
	Fresh sample	
	4·19	5·31
	3·95	5·12
	4·06	4·93
	4·19	5·31
Mean	4·10	5·13
	Stored sample	
	3·07	6·28
	3·14	6·01
	3·07	6·28
	3·29	6·58
Mean	3·14	6·28

It will be seen that in the fresh samples the water soluble potash liberated on treatment with lime are always more than the corresponding potash liberated from the stored samples. This indicates that a portion of the water soluble potash has been fixed and gone out of the solution. The potash extracted with dilute acids is more in the case of the stored samples indicating that the potash gone out of the solution has re-entered the soil complex in an exchangeable form.

The theory of the formation of an insoluble compound cannot be sustained in view of the fact that the N/2 acetic acid used for the extraction of potash cannot decompose the insoluble compound that might have been formed.

Summary

The effect of lime on soil potash under different conditions has been studied. Lime has been found to have no action on soil potash as long as the system is below *p*H 6·0 and above *p*H 7·0. When the system is within this *p*H range the immediate action of lime is to liberate potash from the soil and the liberation is accelerated by the increasing doses of lime. The maximum liberation is recorded at *p*H 7·0. The liberated potash again re-enters the soil complex if the soil is kept in contact with the solution. The fixation of soluble potash is also confined within the above *p*H range.

The disappearance of soluble potash on standing has been shown to be due to the re-entrance of the potash into the soil complex.

Acknowledgements

The author is indebted to G. B. Pal, Esqr., M.Sc., Agricultural Chemist, Bengal, for the kind interest he took in the investigation and to Dr M. N. Chakladar, Physical Chemist, Bengal, for his criticism and valuable suggestion.

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THATCH PLANTING—A MEASURE IN THE CONTROL OF SOIL EROSION

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(Received for Publication on 8 April 1946)

(With Plate XXVII and two text-figures)

Planting of vines on lands with a fairly high slope gradient and specially on the sloping gully walls, has been advocated since some time. The Japanese honey-suckle (*Lonicera japonica*) the Kudzu (*Pueraria thunbergiana, P. phaseoloides*), Lespedeza (*L. striata*) and some others have been widely used for this purpose. Of the above plants, the Chinese vine Kudzu appears to have become the favourite with the American soil-conservationists, specially because of its high growth rate.

The effectiveness of the vines in fighting soil erosion is due, particularly, to their capacity to produce dense mats of shoots which cling to the soil surfaces covering them completely. The soil surfaces are thus protected from the impact of rain drops as well as from the cutting effect of the water running over them.

Besides vines, some trailer grasses are also in use against soil erosion. Of these grasses mention may be made of the Blue grasses (*Poa* sp.), Bermuda grass (*Capriola dactylon*) and the Centipede grass (*Eremochloa ophiuroides*) which are considered outstanding in the United States. The Western Wheat grass (*Agropyron Smithii*) and Range mesquite (*Panicum obtusum*) are also reported to have given excellent results, specially in stabilizing outlet channels, in that country.

But neither the vines nor the grasses have been known to give any protection to the soil, immediately after planting. This is naturally due to the fact that the plants would take some time to establish themselves and to grow to that extent. Turfing with sods has been practised on soil slopes and has met with a fair amount of success in giving immediate results.

The author, while attempting to reinforce a spillway constructed on an earthen dam, by turf sods, was meeting with repeated failures. The sods were being washed down by the spilling water, in spite of their being rammed on by wooden rammers. Thus the bare surface of the fresh loose soil was being repeatedly subjected to easy erosion. It was then decided to thatch the soil surface of the spillway with one of the big grasses of the locality, so that the spilling water could be made to run down over the thatch, without very much interfering with the soil surface below.

Material and method

Saccharum sara (*Sar ghas*) was selected for this purpose because of the following reasons:

1. They are drought resistant and perennial,
2. They have very long leaves, and
3. They are found in plenty in the surrounding areas.

Live plants of *Saccharum sara* were dug out with their roots. They were then laid flat in a dense row across the outer slope of the spillway. All these plants in the row had their shoots hanging downwards and their bases up on the slope. The bases of all these plants were then pushed into the soil with all their roots and planted securely on the spillway. In doing so, care was taken to keep the plants lying on the slope, in the same inverted manner. After this, another similar row was planted in the same fashion, some eight to ten inches above the first row, so that the shoots of this row could cover those of the first row almost up to two-thirds of their lengths. Then similarly a third row above this and then a fourth row and so on till the topmost level of the slope was reached. In this way the entire soil surface was covered, so that the rain water could be made to run down from row to row on the leaves only, as it does on the thatched roof of a hut. Obviously enough the first row of plants was planted right at the base of the slope. A line of turf sods, rammed on to the bases of the plants of the topmost row, was found to add to the resistive property of the entire thatch.

FIG. 1. Portion of a thatch-planted slope, showing the prostrate old shoots and the new erect ones. Foreground shows a barren slope.

FIG. 2. A dam with its thatch-planted spillway. The unsloped top shows turfing.

FIG. 3. Portion of a sloped gully bank showing thatch-planting. The untreated bank is also visible at the top of the right hand side.

It has also been found useful to have the top of the spillway slightly sloped downwards (down hill) before commencing to plant it. This sloping of the top facilitates an easy flow of water over the thatch. An unsloped top, however, has been found to do well under turf.

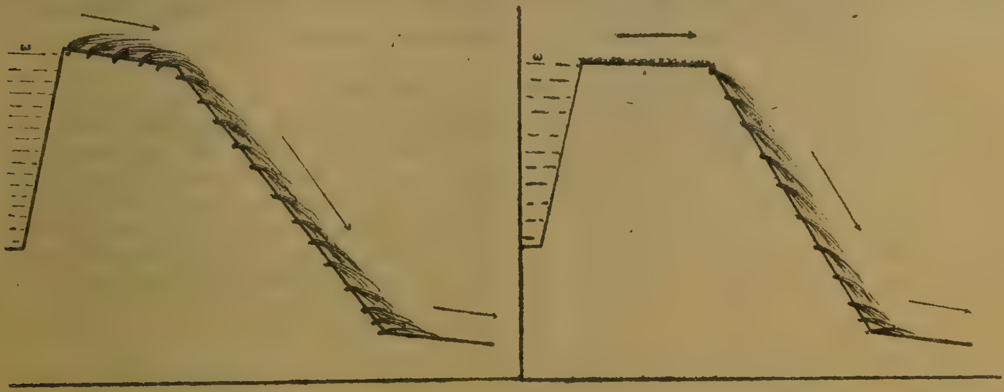

FIG. 1. Cross-section of a bund through its thatch-planted spillway, showing the mode of planting right up to the sloped top

FIG. 2. Same as the other, only with its unlosped and turfed top

For obvious reasons the author has preferred to call this peculiar method of planting, " Thatch-planting ".

Observations

(1) It was seen that all the spillways thatch-planted with the *Saccharum* withstood the showers well.

(2) Moreover, at the end of the rainy season, the plants were seen to put forth new erect shoots, proving that they had, by that time, established themselves on the spillway. The old leaves were found to die and dry up, having served the much needed purpose well, in the very first season.

Thatch-planting on the gully-heads

Thatch-planting has also been tried with success by the author in preventing the upland extension of gully-heads. In doing so the gully banks were sloped and then thatch-planted with *S. sara*.

It was noticed that the plants behaved in the same way as they did on the spillways and gave good results.

Summary

It is quite obvious that thatch-planting would do better if it is done strictly along the contours. It may also be expected that thatch-planting with any other perennial species, specially grasses with long leaves, would give satisfactory results in such works.

Further works on the optimum methods of thatch-planting, its comparative values with other planting methods, and thatch-planting with other species are in progress.

Acknowledgements

The author is indebted to the Imperial Council of Agricultural Research and the Government of Bengal in the Agriculture Department for their kindly financing the scheme and thus giving him the facilities for the investigation.

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THE LIMITING VALUE OF THE BASE EXCHANGE CAPACITY OF SOILS AND CLAYS*

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(Received for publication on 7 June 1946).

It became apparent from the results of determination of the total neutralizable acidity of hydrogen clays [Mitra, Mukherjee and Bagchi, 1940; Mitra, 1940] and of the base exchange capacity (b.e.c.) and lime requirement of acid and desaturated soils [Mukherjee and Ganguli, 1944] that H ions in various affinity levels exist on the surface of the clay particles. Any method aiming at an estimation of the total quantity of these H ions should therefore ensure (i) a high equilibrium *p*H, (ii) a high concentration of the replacing cation which should preferably have a strong electrical adsorption, and (iii) a sufficiently long time of interaction between the H-clay (or soil) and the added electrolyte. The limit to which the *p*H can be raised is set by the stability of the clay complex which is known to decompose at a high *p*H. The concentration of the cation, however, can be considerably increased by making a suitable choice of the salt.

The optimum conditions are more or less satisfied in the following experiments carried out with a view to obtaining an estimate of the limiting b.e.c.

I. Estimation of the lime taken up by the soil or clay on exhaustive treatment spread over two to three days with half neutralized *p*-nitrophenol, a single treatment with which is recommended in Schofield's method [1932]; repeated treatment is expected to improve upon the high value given by a single treatment as compared with other methods [Mukherjee and Ganguli, 1944].

II. Estimation of the lime used up on continued treatment (two to three days) with half neutralized phenol, which gives a higher *p*H (8·5) than the half neutralized *p*-nitrophenol solution, the concentration of the cation (Ca) remaining the same as in (I).

III. Estimation of Mg and Ba adsorbed from solutions of (*a*) $MgSO_4$, (*b*) $BaAc_2$, and (*c*) $Ba(SCN)_2$. The leaching which was done after keeping the soil or clay in contact with the solution for 16 to 18 hours took about six hours. The concentration of the cations was 4·5 N, 4·0 N and 8·5 N respectively in (*a*), (*b*) and (*c*).

Results of these experiments on the hydrogen soil Ks, the hydrogen clay J, and the hydrogen bentonite K, which are described below, are recorded in Table I.

Lab. No. of the soil	Description of the soil	Reference symbol of hydrogen soil or clay
K 16	Loamy soil from Krishnanagar Farm, Nadia (0-6 in.)	Ks
J 51	Acid loam from Jorhat Farm, Assam (0-6 in.)	J
K. B.	Natural deposit of bentonite in Kashmir	K

Table I gives also for comparison the values of the b.e.c.'s obtained by Parker's [1929] and Schollenberger's [1930] methods.

* The results given in this paper were published in the Annual Report for 1941-42 of the Working of the Scheme of Research in to the Properties of Colloid Soil Constituents financed by the Imperial council of Agricultural Research and directed by Prof. J. N. Mukherjee [C. F. also Mukherjee, J. N., Mukherjee, S. K. and Gupta, S. L. (1942). rPoc. 99th Indian Sci. Cong. Assoc., 304]

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TABLE I

Base exchange capacities in m.e. per 100 g of the reacting substances as obtained by different methods.

System	Parker	Schollenberger	Schofield; single treatment	Schofield; repeated treatment I	Ca adsorbed from phenol-lime solution pH 8·5 II	Mg adsorbed from 4·5 N $MgSO_4$ III(*a*)	Ba adsorbed from 4·0 N $BaAc_2$ III(*b*)	Ba adsorbed from 8·5 N $Ba(SCN)_2$ III(*c*)
H-soil, Ks	9·0	9·3	11·5	15·8	14·8	..	..	..
H-Clay, J	33·1	..	..	..	35·4	32·9	39·1	..
H-bentonite, K	112·8	..	116·8	119·5	..	109·7	114·4	125·0

DISCUSSION OF RESULTS

A higher b.e.c. is obtained with I than a single treatment with Schofield's solution.

A higher value with II than with I, which is expected in view of a higher equilibrium pH in II, is observed only in the case of the hydrogen clay, J.

A lower b.e.c. is obtained with III(*a*) than with Parker's method though the concentration of the cation is much higher. This is probably due firstly to a weaker electrical adsorption of Mg than Ba, and, secondly, to a weaker buffering of the sulphate solution as compared with the acetate, which gives rise to an equilibrium pH definitely lower than 7·0 in the case of the sulphate.

A higher value is obtained with III(*b*) than with Parker's method which is expected in view of a much higher concentration of Ba in III(*b*). A higher value than with I and II in the case of the hydrogen clay, J, is obtained with III(*b*) but in the case of the hydrogen bentonite, K, a lower value is obtained than with I.

The highest value of the b.e.c. is obtained with III(*c*). The very high concentration (8·5 N) of the strongly adsorbable Ba ions combined with the pronounced buffering which is observed in the neighbourhood of pH 7·0 thus brings into a reactive condition the largest quantity of H ions.

It is not claimed that this method, III(*c*), measures all the H ions. Very probably it does not, and a higher value may be obtained under more favourable conditions. In the light of the present investigation such favourable conditions would be created by ensuring a higher pH and a higher concentration of the cations. For all practical purposes it may not be necessary to satisfy these extreme conditions and the value obtained under more moderate conditions, e.g. those obtaining in Parker's and Schollenberger's methods may be considered suitable.

SUMMARY

An attempt has been made to estimate the maximum amount of H ions (or b.e.c.) of a hydrogen soil, a hydrogen clay and a hydrogen bentonite and thereby to obtain an idea of the limiting number of H ions associated with a known quantity of the reacting material.

Repeated treatment with *p*-nitrophenol-lime solution, method I, gives a higher b.e.c. than single treatment.

The amount of lime taken up by a hydrogen soil and a hydrogen clay from a phenol-lime solution, method II, at a fixed pH of about 8·5 is higher than that obtained by Schofield's *p*-nitrophenol-lime method at pH 7·1.

The b.e.c. calculated from the amount of Mg adsorbed from a neutral saturated solution of $MgSO_4$ (4·5 N) is lower than that given by Parker's method, although the cation concentration in the former is much higher. This is possibly due to the weaker electrical adsorption of Mg as compared with Ba and a weaker buffering in the case of the sulphate than the acetate solution.

The amount of Ba adsorbed from a saturated solution of $BaAc_2$ (4·0 N) is higher than those obtained by Parker's method and by methods I and II in the case of a hydrogen clay and a hydrogen bentonite. But the b.e.c. calculated from the amount of Ba adsorbed from a neutral saturated solution of $Ba(SCN)_2$ is the highest obtained with a hydrogen bentonite. The very high concentration (8·5 N) of the strongly adsorbable Ba ions combined with the pronounced buffering which is observed in the neighbourhood of pH 7·0 thus brings into a reactive condition the largest quantity of H ions.

It is concluded that for all practical purposes it may not be necessary to satisfy the extreme condition envisaged above and the value obtained under more moderate conditions, e.g. those obtaining in Parker's and Schollenberger's methods, may be considered suitable.

Acknowledgement

Our thanks are due to Prof. J. N. Mukherjee for his kind interest and helpful suggestions in carrying out this work.

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SEASONAL VARIATION IN THE ALKALOIDAL CONTENTS OF THE LEAVES OF *ATROPA ACCUMINATA* ROYLE (INDIAN BELLADONNA), I

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(Received for publication on 26 March 1946)

Comparative histological studies of Indian Belladonna and Atropa Belladonna by Colin Melville [1944] reveal that the Indian Belladonna is *Atropa accuminata* and is different from *A. belladonna* Linn in certain respects.

Atropa accuminata grows wild in the Himalayas from Simla to Kashmir at an altitude of 6,000 to 12,000 ft. It also grows in Beluchistan and in the North-West Frontier Province. It is very common in the Kashmir forests and forms the bulk of the Indian belladonna of commerce both in the Indian and foreign markets.

In order to determine the proper time of collection of the leaves of Indian belladonna, i.e. when they contain maximum percentage of alkaloids, fortnightly collections of the leaves were made from different forest areas. They were collected from the beginning of August till late in November and were dried for first three days in the sun and rest of drying was completed in shade. The results of analysis are given in Table 1.

TABLE I

Analyses of Indian belladonna leaves at different times

Localities		Periods of collection							
		1-8-1945—16-8-1945 Plant begins to flower		1-9-1945—16-9-1945 Flowering stage		1-10-1945—16-10-1945 Flowers shed off		1-11-1945—16-11-1945 Fruit formation stage	
Sindh Range (altitude 7,000 ft.)	Percentage of moisture	7·9	8·2	8·7	7·6	8·4	8·1	9·0	9·1
	Percentage of total alkaloids	0·94	0·65	0·42	0·51	0·41	0·51	0·1	0·35
Gulmarg Range (altitude 7,500 to 8,000 ft.)	Percentage of moisture	8·3	8·3	..	8·4	8·9	8·5	8·9	..
	Percentage of total alkaloids	0·58	0·45	..	0·43	0·32	0·34	0·31	..
Rajwar Range (altitude 6,000 ft.)	Percentage of moisture	7·1	..	..	..	..	..	7·4	..
	Percentage of total alkaloids	0·81	..	..	..	..	..	0·47	..

From perusal of the data it will be seen that alkaloidal percentage is maximum in the leaves collected in the beginning of August, i.e. when the plant starts flowering. As the season advances, the alkaloidal contents of the leaves decrease and is minimum at the stage of fruit formation which takes place in November. The proper time of collection of the leaves it would appear, therefore, is just when the plant starts to flower in August.

Specimens of the leaves of the *A. accuminata* were also collected from different forest areas in the beginning of August and were dried uniformly in the sun for first three days and then completed the rest of drying in shade. The results are tabulated in Table II.

TABLE II

Analyses of A. accuminata *leaves from different forests*

Locality	Altitude in ft.	Percentage of moisture	Percentage of total alkaloids
Sindh Range	7,000	7·9	0·94
Gulmarg Range	7,500	8·2	0·58
Rajwar Range	6,000	7·1	0·82
Kuthar Range	6,500	8·4	0·58
Hirpur Forests	7,500	8·7	0·51
Drang Nursery	6,500	8·2	0·91

A study of the results in Table II shows that the leaves of the Indian belladonna contain a much higher proportion of alkaloids as compared with 0·3 per cent of total alkaloids laid down in British Pharmacopœia. A number of specimens of the roots were also collected and analysis gave up to one per cent of total alkaloids as compared with 0·4 per cent of British Pharmacopœia.

The method of British Pharmacopœia [1932] P. 84 and of Fifth Addendum to the British Pharmacopœia P. 1 was used for the analysis of the above samples.

We are grateful to Col. Sir Ram Nath Chopra for his help and guidance in this work.

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BIOLOGICAL DECOMPOSITION OF GREEN MANURES

II. THE EFFECT OF NATURALLY OCCURRING TANNINS ON DECOMPOSITION

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(Received for publication on 19 July 1945)

(With one text-figure)

In part I of this series [1945] it was pointed out that although tea leaf gave a high negative nitrogen factor during decomposition it showed no signs of ammonification over a period of 35 days despite normal losses of dry matter. This negative nitrogen factor is thus equivalent to its nitrogen loss and is contrary to well established conception of nitrogen transformation during aerobic fermentation. This phenomenon appeared to be puzzling and experiments had to be devised to confirm or confute the possibility that elementary nitrogen is produced under aerobic conditions which for other materials of a similar C : N ratio ensure normal mineralization. Results bearing on such a phenomenon are described and discussed in this communication.

Technique

The leaves of a number of tanniferous species were fermented in the way described previously. In addition a few of them were decomposed in sealed bottles through which a stream of NH_3-free air was bubbled continuously for a period of 60 to 80 days. After passing through the decomposing mass the gaseous strain ensuing from the bottle was passed through standard acid.

The sequence of apparatus through which the air flow passed was (1) H_2SO_4 scrubber, (2) distilled water scrubber, (3) decomposition bottle, (4) standard acid absorption tube (U-tube filled with glass beads), (5) guard tube similar to (4), and (6) Buchner pressure regulating flask attached to filter pump.

The decomposition bottle was an ordinary wide-mouthed gas washing bottle.

All components were inter-connected by presure tubing sealed with collodion. Methyl red indicator was used for titration and the absorption tubes which were changed when necessary. Acid in the U-tubes was titrated periodically care being taken to immediately put in spare tubes with fresh acid. The ammonia equivalent of the acid used up was then calculated and the percentage of mineralization of the total nitrogen in the material was then plotted against the period in days. A balance sheet of nitrogen can be constructed after analysing the contents of the bottle for loss of dry matter, total NH_3-N, NO_3-N, and NO_2-N. NO_2-N was estimated by the method described by the writer [1939].

Experimental

(*a*) *Periodic decomposition of tea leaf.* On account of the anomalous behaviour of tea leaf it was considered desirable to follow its decomposition at different intervals to find out whether ammonification occurred at any particular stage. A set of five bottles was laid down and one each was examined every fortnight over a period of 60 days. One was left decomposing for one year. The results of analyses of these bottles are given in Table I. No detectable ammonia accumulated in the decomposed mass even though the experiment proceeded for a longer period than as usually required to show vigorous mineralization. Tannin which appeared to be the only constituent causing such an anomaly was also determined at each stage of decomposition.

It will be noted that a major portion of tannin disappeared in the first fortnight but small amounts persisted even beyond 60 days. Formation of detectable amounts of nitrite after 365 days suggests that small and fugitive quantities might have appeared even in the earlier stages but they could not perhaps be detected because the method was not sensitive enough for such fugitive amounts. This may be one stage in the process leading to the losses of nitrogen in the gaseous form. It is also possible that the presence of tannin modified the flora and that its antiseptic properties inhibited the multiplication of the type of fungi and bacteria [Knudson, 1913 ; Neirenstein, 1934] responsible for the rapid mineralization of the plant protein.

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TABLE I

Periodic decomposition of tea leaf
(On 100 gm. of original material)

Period in days	Dry matter recovered	NH_3-N	NO_2-N	Organic N	Nitrogen factor	Tannin
0	100	..	..	2·97	..	7·93
15	82·1	..	..	2·63	—0·34	1·89
30	66·8	..	..	2·54	—0·43	1·35
45	63·0	..	..	2·42	—0·55	1·09
60	57·0	..	..	2·41	—0·56	0·99
365	45·6	..	0·08	2·06	—0·91	..

(*b*) *Effect of tea tannin and commercial tannic acid on the mineralization of organic nitrogen in Gliricidia and other materials.* In order to clarify the part played by the tannin in controlling nitrogen exchanges, various combinations of tanniferous and non-tanniferous nitrogenous material were mixed and allowed to decompose. In the first class were tea leaf, its extract and residue, and commercial tannin. In the second class were *Gliricidia* leaf, gelatin and peptone. The actual combination are set out in Table II.

The results of analysis are summarized in Table II. It will be noted that there was mineralization of nitrogen in every case except tea leaf and its water extracted residue.

TABLE II

Effect of tea leaf, its water extract and commercial tannic acid on the mineralization of nitrogen in Gliricidia *leaf and peptone*

Material	(Results expressed on 100 gm. original material)					
	Residual Dry matter	Initial total nitrogen	Final total nitrogen	Ammoniacal nitrogen	Organic nitrogen	Nitrogen factor
(*a*) *Gliricidia* 20 gm.	50·6	4·02	2·74	0·92	1·82	—2·20
(*b*) Tea leaf 20 gm.	63·0	2·97	2·42	*nil*	2·42	—0·55
(*c*) Water extracted tea leaf Cf. (*b*) . . .	81·0	2·72	2·59	*nil*	2·59	—0·13
(*d*) *Gliricidia* 20 gm. and tea leaf extract (0·037 gm. N)	50·7	3·70	2·94	0·89	2·05	—1·65
(*e*) *Gliricidia* 10 gm. and tea leaf 10 gm.	70·3	3·50	3·25	0·69	2·56	—0·94
(*f*) *Gliricidia* 20 gm.+tannic acid 4 gm. . .	49·1	3·02	3·20	0·57	2·63	—0·39
(*g*) Tea leaf 20 gm. + peptone (0·20 gm. N) .	63·1	3·97	3·06	0·51	2·55	—1·42
(*h*) Filter paper 10 gm. + Gelatin-Tannin precipitate (0·54 gm. N)	71·4	3·51	2·34	1·07	1·27	—2·24

Decomposition of tannin materials other than tea leaf. Results in Table II clearly indicate that the external addition of tannin as tea leaf extract or commercial tannic acid did not affect the mineralization of plant protein to the same extent as when present *in situ* in tea leaf. It was therefore thought necessary to study the decomposition of some tanniferous species on similar lines to tea leaf. The data in Table III show that although some ammonification has occurred it is hardly comparable with the amounts of ammonia recovered from other green manures containing nearly identical quantities of organic nitrogen. It is apparent therefore that tannin does exercise some effect on mineralization of nitrogen in tannin material. *Terminalia chebula*+*Gordonia* did not undergo much change during decomposition because of the initial low nitrogen content: 1·77 per cent nitrogen in a material is just the borderline above which the material will decompose without any external source of available nitrogen or below which it is resistant to decomposition [Lyon *et al.* 1923]. Tannin figures in decomposed materials show that appreciable proportion of tannin persists even after a decomposition of about 5 to 6 weeks. For a classification of the various tannin materials examined here, a reference may be made to a previous publication by the writer [1942].

TABLE III

Effect of naturally occurring tannin on the decomposition of tannin materials

Material	(Results expressed on 100 gm. original material)							
	Dry matter recovered	Initial total N	Final total N	NH_3-N	Organic N	Nitrogen factor	Original tannin	Final tannin
Caesalpinia bonducella .	48·5	3·21	2·60	0·19	2·40	—0·81	4·71	1·50
C. coriaria . . .	76·0	1·99	1·63	20·05	1·58	—0·41	18·23	6·43
C. sappan . . .	56·0	2·73	2·69	0·31	2·38	—0·35	1·65	1·08
Pterocarpus indicus .	52·5	3·50	3·34	0·67	2·67	—0·83	3·47	1·89
Terminalia belerica Roxb.	77·5	2·41	2·44	0·23	2·21	—0·20	14·03	2·23
T. chebula . . .	92·0	1·73	1·74	..	1·74	*nil*	26·46	23·41
Gordonia imbricata . .	83·2	1·77	1·79	0·15	1·61	—0·16	15·31	..

Decomposition studies by the new technique. The quantity of plant material taken for decomposition was fixed at 10 gm. in each case. For decomposition in the soil 90 gm. of soil were mixed with 10 gm. of tea leaf powder passing through a 64-mesh sieve. Ninety grams of soil was aerated in a separate bottle as a control. Known weights of glass pellets were added in every bottle to prevent anaerobic conditions through the formation of lumps. Before analysis of the decomposed mass, these pellets were removed. Tannin-free tea leaf was obtained by grinding fresh tea flush with well-washed iron free sand in alchol just sufficient to keep the mixture immersed. This operation was repeated till the residue was colourless and the extract gave a negative test with ferric chloride. The process is very tedious and takes nearly two to three working days to obtain a tannin-free product. Ordinary water or alcohol extractions in a Soxhlet do not free the material entirely of tannin. Repeated grinding with sand ruptures the plant cell and facilitates extraction of tannin. Since the separation of the tannin-free material from sand is a difficult process, the pulverized mass itself was used for decomposition after determining its organic matter and toral nitrogen content. In this case too the organic matter for decomposition was fixed at 10 gm. At the close of the experiment the contents of the bottles were analysed for the constituents mentioned previously. The sand and tannin-free mass was difficult to handle because of its messy character. It was therefore shaken with distilled water after separating the glass pellets. Solids were allowed to settle and

Separated from the supernatant liquor. Both the solids and the supernatant liquor were then examined separately. For soil mixtures ammoniacal and nitric nitrogen were determined by the McLean and Robinson method [1924]. The course of mineralization is represented graphically in Fig. 1

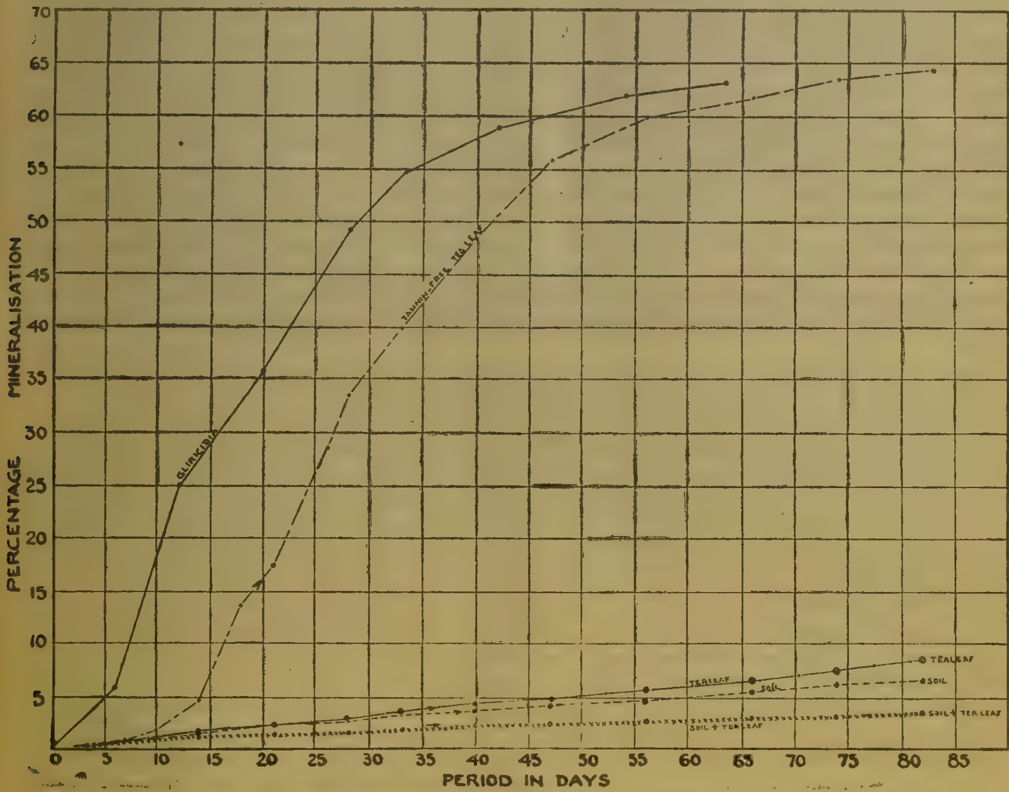

Fig. 1. Mineralization of protein in tannin and tannin-freed materials

Decomposition by the new technique in which there is no chance of loss of nitrogen as ammonia confirms the previous findings that tea leaf does not ammonify to the same extent as other green manures of a similar nitrogen content and that the high negative nitrogen factor must therefore be due to loss of possibly elementary nitrogen. Secondly, tannin-free tea leaf ammonified like *Gliricidia* without any loss of elementary nitrogen as seen from Fig. 1. These two observations coupled with the course of ammonification of other three tanniferous species under similar condition also confirm that tannin directly affects ammonification in tannin materials. Ammonification of tea leaf in the soil might be due to the following causes : (1) vigorous aeration which rarely occurs under field conditions, (2) organisms essential for ammonification might have been present in abundance in the soil, (3) presence of organisms which might have readily oxidized phenolic and ketonic bodies : such organisms occur in certain soils [Waksman, 1927], and (4) adsorption by the soil colloids of toxins developed during fermentation of phenolic bodies.

Nitrification tests with tannin materials. In order to estimate the availability of nitrogen in any material the most common test applied is that of nitrification in the soil. The same test was applied to tannin material to see how it compared with the findings in the previous section. To avoid any complications arising out of other consitutents present in the soil, pure washed sand was

used as a medium for these experiments ; 100 gm. sand was well-mixed with the material and ground to pass an 84-mesh sieve. Nitrogen in each container was adjusted to 40 p.p.m. Moisture content was maintained at 10 per cent. Each container also received 1 c.c.of fresh inoculum from a well-manured garden soil. Every treatment was quadruplicated and the temperature of incubation was 30°C. Two sets were conducted : (1) nitrification of tannin materials, and (2) effect of these materials on the nitrification of blood meal. For the second set the amounts of nitrogen added in different forms were 20 p.p.m. bringing the total nitrogen to 40 p.p.m. with blood meal. Caffeine was also included in the set since nearly 25 to 30 per cent of nitrogen in tea leaf is accounted for by caffeine. After five weeks all the cultures were extracted with normal sodium chloride and the ammonical and nitric nitrogen were determined by the McLean and Robinson method [1924]. The results are given in Tables IV and V ; positive or negative sign denotes increment or diminution over the control values. It will be noted that tannin materials in general depressed the yield of mineral nitrogen in both the sets, tea leaf in particular causing the greatest inhibition. The action of *Terminalia chebula* is anomalous but its effect is the same in both the sets. Caffeine nitrogen mineralized like blood meal and hence could not be taken as a cause of the anomalous behaviour of tea leaf. Nitrification tests while confirming the previous findings throw doubt on the findings of Wad and Ghosh [1938] who obtained large increments in mineral nitrogen when tea leaf was decomposed in the soil.

TABLE IV

Nitrification of tannin materials in sand cultures

Materials	NH_3 p.p.m.	NO_3 p.p.m.	Percentage of tannin
Sand (control)	8·40	....	....
„ + *Caesalpinia sappan*	—0·14	+0·14	1·65
„ + „ *coriaria*	—0·42	—0·14	18·23
„ + *Plerocarpus indicus*	—0·14	+0·14	3·47
„ + Tea leaf	—2·24	—0·21	7·93
„ + *Terminalia belerica*	—2·52	+0·63	14·03
„ + „ *chebula*	+1·54	..	26·46
„ + Caffeine	+2·80	+1·96	..
„ + Blood meal	+1·70	+3·52	..

TABLE V

Effect of tannin materials on the nitrification of blood meal in sand

Material	NH_3 p.p.m.	NO_3 p.p.m.	Percentage of tannin
Sand+blood meal (control)	10·10	3·51	..
Sand+blood meal caffeine	+2·36	+1·94	..
Sand+blood *Caesalpinia coriaria*	—0·86	—0·44	18·23
Sand+blood+*Piterocarpus Indicus*	—1·98	—0·55	3·47
Sand+Tea leaf	—4·08	—0·44	7·93
Sand+*Terminalia chebula*	+1·78	—0·72	26·46
Sand+ *T. belerica*	—2·40	—1·80	14·03

Discussion

Sufficient evidence has been adduced to show the inhibiting effect of tannin on the course of mineralization of nitrogen in tanniferous species during decomposition. The effect of tannin on such a phenomenon is particularly startling in the case of tea leaf where no ammonia accumulated in the decomposed mass although there was a constant fall in the nitrogen factor. That tannin has a direct influence on ammonification of nitrogen in tea leaf has been clearly demonstrated by the spontaneous mineralization in the tannin-freed tea leaf. This adverse effect of tannin on ammonification may be attributed to two causes : (1) some association between tannin and protein and (2) the toxic effect on the growth of fungi responsible for decomposition and subsequent ammonification. The former is unlikely since tannin occurs in solution in the cell sap ; and because tannin precipitates albuminous matter, it follows that the layer of protoplasm around the tannin vesicles must be impermeable to it ; if this were not so the protoplasm would be tanned in the presence of tannin. Secondly, association of tannin and protein is untenable for when tannin materials are extracted with water only insignificant amounts of protein are removed whereas 95 per cent of the tannin goes into solution. The second cause appears to be the most plausible for there is definite evidence to the effect that tannins are toxic to certain organism especially to fungi [Knudson, 1913 ; Shrikhande, 1940].

But the loss of nitrogen without any apparent ammonification, or ammonification in insignificant amounts, when tea leaf decomposed alone needed a closer examination. The new technique in which no ammonia could escape due to volatilization made it possible to examine more closely the anomalous behaviour of tea leaf by drawing up a balance sheet of nitrogen before and after the experiment. The results provide further presumptive evidence of the loss of nitrogen in the gaseous form under undoubtedly aerobic conditions. It may be questioned as to why tea leaf alone in the tanniferous species behaves in this exceptional way. In addition to tannin, tea leaf contains a formidable grouping of other phenolic and ketonic bodies and purine bases. Such grouping is rarely met with in other plant tissues including the tanniferous species. It is likely that these phenolic and ketonic bodies may be contributing to such an unexpected loss of elementary nitrogen. For instance in some cases aldehydes and purine bases have acted as reducing agents and have helped reduction processes in the soil by evolving gaseous nitrogen [Dixon and Thurlow, 1924]. This view finds support from the results on the ammonification of nitrogen in tannin-freed tea leaf where besides tannin, other phenolic and ketonic bodies are also extracted by alcohol. There the recovery of nitrogen is complete without any loss of nitrogen. Exceptional behaviour in other ways of tannin materials in general and of tea leaf in particular has been reported by the writer on previous occasion [Shrikhande 1940 *a* and *b* ; Shrikhande 1944, *a* and *b*].

The mechanism of the loss of elementary nitrogen is yet to be worked out. Two or three tentative suggestions are however offered :

(1) Appearance of traces of nitrites under the reducing action of tannins ; such likelihood has been pointed out earlier in this article. Nitrite may therefore be reacting with animo groups; both of them are formed in the decomposition of organic matter rich in nitrogen accompanied by the incomplete liberation of ammonia.

$$—CH_2—NH_2+HNO_2 \longrightarrow CH_2\,OH+H_2O+N_2$$

$$NH_3+HNO_2 \longrightarrow N_2+2H_2O$$

(2) Some ammonium nitrate may be formed under vigorous conditions of aeration in the new technique. This ammonium nitrate is reduced to nitrite by the reducing atmosphere created by tannin. The ammonium nitrite is subsequently decomposed into nitrogen and water in the presence of sunlight [Dhar, 1920].

(3) On the strength of Harden's [1901] observation, presence of nitrite is not necessary to obtain a loss of gaseous nitrogen during the decomposition of a carbohydrate in presence of proteins. Harden using a peptone-glucose medium inoculated with *B. coli* obtained 7·5 c.c. of gaseous nitrogen.

Although this loss of elementary nitrogen from tea leaf during fermentation looks anomalous, it may nevertheless throw some light on the losses of nitrogen from soils under favourable condition of oxidation. The researches of Lipman and Blair [1921], Russell and Richards [1917], Shutt

[1910] and of others show that a good deal of nitrogen is lost in the gaseous state from soils or manure heaps. The loss of nitrogen in this process may be more than double the amount of nitrogen taken up by the plant grown on the soil. Nearly 70 per cent of the added nitrogen is reported to have been lost when wheat plots on Broadbalk at Rothamsted had received 14 tons of farmyard manure containing 200 lb. of nitrogen per acre. A greater loss of nitrogen is observed when manure is composted under aerobic than under anaerobic condition. Till now no satisfactory explanation has been offered for such prodigious losses of nitrogen. Since dung and liquid manure contain large amounts of phenolic bodies [Liechh and Moosers, 1906] and fungal tissue also contains some tannin, it is likely that these phenolic bodies act on the organic matter either in the soil or in the manure heap in the same manner as in the decomposition of tea leaf with a consequent loss of gaseous nitrogen.

Summary

The question of mineralization of N in tanniferous species and the loss of gaseous N from tea leaf during decomposition has been investigated in some detail by the old and new techniques.

No ammonification was observed at any stage of decomposition of tea leaf between o to 365 days by the old technique although there was a constant fall in the nitrogen factor.

The presence of tannin in any of the three forms —as tea leaf, as its water extract and as commercial tannic acid – depressed the ammonifications of nitrogen in *Gliricidia*. A fairly good mineralization of peptone in presence of tea leaf and gelatin-tannin complex denotes that the state of tannin in which it is present has some effect on mineralization.

The decomposition of other tannin materials indicates that although some ammonification occurs it is hardly comparable to other non-tan green manures of the same nitrogen content. Determination of tannin in the decomposed products show that tannin in appreciable amounts persists even after a period of six weeks decomposition.

Studies by the new technique confirmed the previous findings that tannin has a direct bearing on the course of ammonification of tanniferous species. Tannin freed tea leaf ammonified as rapidly and spontaneously as *Gliricidia*.

Nitrification tests with tannin materials and the effect of these materials on the nitrification of blood meal denote that tannin inhibits mineralization of nitrogen in blood meal.

A discussion on the possible causes of tannin interference in ammonification leading to losses of N in the elementary form during aerobic fermentation has been appended.

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BIOCHEMICAL INVESTIGATION ON JUTE RETTING

I. ISOLATION OF MICRO-ORGANISMS FROM JUTE RETTING PIT, THEIR CHARACTERIZATION AND THEIR ACTION ON JUTE STEMS

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(Received for publication on 11 April 1946)

A VERY important step in jute production is retting, but the principles underlying this step are hardly understood by out cultivators. They practise the cheapest process, steeping the plant in stagnant or slowly moving water. This produces micro-biological action on the plant which is the basis of fibre separation. Micro-biological action being controllable, a standard product may be ensured by manipulating the Micro-biological action on jute while it is being retted. This requires scientific treatment during retting. 'It is remarkable', comments Mr. S. G. Barker [1935], 'that this process which is the basis of the production of good manufacturing material of the mill has received so little scientific attention', and he strongly urges that retting should be subjected to a thorough scientific investigation.

Defects due to uncotrolled retting are apparent : over-retting leads to a loss of the substance and under-retting degrades the quality of the product. Retting to a proper degree eliminates these defects and hence the necessity of continuing further research for improvement and also of making available to the cultivator the knowledge already acquired.

The possibility of chemical retting has also been suggested by some authorities, but it is costly in comparison with the micro-biological process. This is also testified by Nodder [1941], and by Nodder, Sarkar and Chatterjee [1944]. Recently Baruah and Baruah [1944] claim to have succeeded in isolating a highly active strain which rets jute in 8-10 hours, but very little is as yet made known about it.

To understand the micro-biology of jute retting, the identification of the active organisms should be the first step. Isolation of the organisms has previously been attempted by Adati and Yoshimura [1939]. They isolated 11 strains of aerobic bacteria from jute retting solution, but they did not study the effect of their growth on jute stems. Later Katagiri and Makahama [1940] actually isolated an aerobic bacteria capable of retting jute stems from jute retting vat. They characterized the isolated strain and named it *Bacillus corchorus*. Thaysen and Bunker, however, suggest that the retting phenomenon is a symbiotic one, but this requires confirmation.

The present communication deals with the isolation of micro-organisms from jute retting pit, their characterization and their action on jute.

Experimental

The procedure adopted here for the isolation and characterization of micro-organisms in jute retting is as follows :

For growing the organisms concerned in the jute retting process the modified Czapek medium of the following composition have been found to be the most suitable :

Cane sugar	30·0 gm.
$NaNO_3$	1·0 gm.
$FeSO_4$	0·1 gm.
$MgSO_4$	0·5 gm.
K_2HPO_4	1·0 gm.
Water	1 litre.

The *p*H of the solution was adjusted at 7·2, then the solution was sterilized at 15 lb. pressure for 15 minutes. The above medium was inoculated separately with retting water and also with retted jute obtained from the retting pit of the Government Agricultural Farm at Chinsurah through the kind co-operation of the Superintendent of the farm and the incubated at 35°C. both aerobically and anaerobically.

Anaerobic condition was obtained in the following way: In a vacuum desiccator, pyrogallic acid and a slight excess of 40 per cent NaOH solution were placed. Then the inoculated flasks or test tubes or petri dishes, as the case may be, were placed in the desiccator and also a test tube containing glucose peptone medium inoculated with *Bacterium xylinum*, which is an aerobe. Then the desiccator was evacuated by a pump and filled with oxygen-free nitrogen and then it was placed in an incubator at 35°C. The absence of growth of the *Bacterium xylinum* in the test tube in the desiccator proved that the atmosphere inside the desiccator is anaerobic.

For the isolation of the organisms, platings were performed in the same medium with the addition of 2·5 per cent agar and incubated at 35°C. In the case of the aerobic bacteria, the colonies with their characteristic shapes become visible on the second day of the incubation and in the case of the anaerobic bacteria on the fourth day. The colonies of different shapes were separated and again plated. The process was repeated until there remained only one kind of colony on each plate.

By the above method eight strains of aerobic bacteria and five strains of anaerobic bacteria have been isolated.

The characteristics of the facultative anaerobic bacteria are given in Tables IA and IB and of the aerobic bacteria in Tables IIA and IIB.

The carbohydrate media used consisted of 8 c.c. of 2 per cent carbohydrate, 1 per cent peptone, 0·1 c.c. of litmus solution and an inverted Durhams tube for the detection of gas production. The reaction of the media was adjusted at pH 7·2. The media were sterilized at 10 lb. steam pressure for 15 minutes in a steam sterilizer. Jute stem medium contained green jute stem cuttings 5 per cent and water and then this medium was sterilized at 15 lb. pressure for 15 minutes. All other media used in the tubes were prepared according to the directions of Eyre, and Simmons and Gentzkons.

The isolation of cellulose fermenting bacteria was attempted with a medium of the following composition:

$MgSO_4$	0·5 gm.
NaCl	0·5 gm.
Filter paper	2·0 gm.
$CaCO_3$	1·0 gm.
KNO_3	1·0 gm.
Water	500 c.c.

The pH of the solution was adjusted at 7·1 and the flasks were sterilized at 20 lb. steam pressure for 20 minutes. Inoculations were made both with retting water and retted jute and incubated at 36°C. but even after 3 months' incubation, no visible sign of growth of any organism was observed.

For the isolation of the sulphur bacteria, a medium of the following composition was made:

$Na_2S_2O_3$	5·0 gm.
$MgCl_2$	0·1 gm.
NH_4Cl	0·1 gm.
Na_2HPO_4	0·2 gm.
Water	1·0 litre.

The solution was sterilized at 15 lb. steam pressure for 15 minutes. The above medium was inoculated with retting water. After 15 days incubation at 30°C. a thin white pellicle of sulphur was formed. It was then purified by plating with the same medium with the addition of 2·5 per cent agar an incubated at 30°C. This is a very small, thin rod-shaped organism occurring singly and deriving its energy from the oxidation of sulphides, thiosulphates or sulphur. The optimum temperature of growth is 30°C. In liquid media, it forms sulphur. In solid media, it forms small circular yellow colonies. This is an aerobe and grows best in alkaline pH. It is unable to ret jute stem medium. According to Bergey's classification it has been identified as *Thiobacillus thioparus*.

Isolation of fungi.

For the isolation of fungi in the retting water and the retted jute, the aforesaid modified Czapek's medium was used with this difference that its pH was adjusted at 6·4 with N/10 HCl. By repeating the process of retting as before, four different strains of fungi were isolated. They were marked as

TABLE IA

Facultative anaerobic bacteria

Marking of the strain	Shape	Spore	Flagella	Dextrose-gelatine stab	Dextrose broth
N_1	Short, slender rods occurring singly	Terminal spore, club-shaped	Peritrichous flagella	Liquefied	No growth
N_2	Long rods occurring singly	Do.	Do.	Do.	Do.
N_3	Rods occurring singly	Central spore, rods not swollen during sporulation	Do.	No liquefaction	Turbid
N_4	Do.	Do.	Flagella absent	Liquefied	Turbid and gas
N_5	Short, thick rods with rounded ends occurring singly and in pairs	Do.	Peritrichous flagella	No liquefaction	Turbid

Mark	Potato slant	Litmus milk medium	Dextorse agar slant
N_1	No growth is visible, but potato turns brown	Coagulation, acid, gas	White growth of irregular shape
N_2	No growth	Do.	Do.
N_3	Creamy raised points	Do.	White spindle shaped colony
N_4	No growth	Do. slimy	Thin pale blue layers
N_5	Yellowish raised points	Coagulation, acid, gas	Grayish, moist and spreading colony

Common characteristics : Motile, Gram positive, optimum temperature is 35°C. do not blacken brain medium, do not liquefy coagulated albumin and blood serum-media, do not reduce nitrate in nitrite medium, do not grow and do not from indole in peptone water medium.

TABLE IB

Facultative anaerobic bacteria

Mark of the strain	Jute stem medium	Name of the strain according to Bergy's Manual of Determinative Bacteriology
N_1	Jute is retted in 14 days at 35°C	Clostridum felsinae
N_2	Jute is retted in 24 days at 35°C	Do.
N_3	Jute is not retted even after 2 months incubation at 35°C	Clostridium butyricum
N_4	Do.	Clostridium mucosum
N_5	Jute is retted in 15 days at 35°	Clostridium butyricum

Only N_1 gives orange pigments in alkaline media. The pigment is insoluble in ether, chloroform, and benzol.

Common characteristics : Do not grow on cellulose, glycerin media, and produce acid and gas with glucose ructose, galactose, mannose, lactose, sucrose, salycein, inositol, arabinose, starch, mactose and xylose media.

Table IIA

Aerobic bacteria

Mark of the strain	Shape of the bacteria	Spore	Flagella	Optium temperature of growth	Potato slant
R_1	Rods occurring singly Small during sporulation	Endospore present. Spore central	Peritrichous flagella	35°C	First gray, and then pink
R_2	Long rods occurring singly, Swell during sporulation	Do.	Do.	35°C	Slimy film with gas formation
R_3	Long rods, occur singly, and in chains. Swell during sporulation	Do.	Do.	30°C	Thick white growth later turning yellow
R_4	Slender rods, occur singly	Do.	Do.	35°C	White growth
R_5	Rods occur singly and in pairs	Do.	Do.	30°C	Brown, wrinkled growth
R_6	Rods occur singly and swell at sporulation	Endospore present. Terminal spore	Polar flagella	35°C	Heavy growth with gas formation
R_7	Rods with truncate ends and occur singly	Endospore absent	Flagella absent	Below 25°C	No growth

Mark of the strain	Gram stain	Litmus milk	Starch medium	Nitrate medium incubated for 7 days
R_1	Positive	Alkaline, peptonized after 6 days incubation	Acid formation, and starch hydrolized	Nitrate is reduced
R_2	Do.	Coagulation, acid and gas	Acid, gas formation and starch hydrolized	Do.
R_3	Do.	Alkaline and peptonized	Acid formation, and starch hydrolized	Do.
R_4	Do.	Peptonized and acid	Do.	Do.
R_5	Do.	No coagulation, but peptonized	Starch is hydrolized	Nitrate is not reduced
R_6	Do.	Coagulation, acid and gas	Acid formation and starch is hydrolized	Do.
R_7	Negative	Alkaline	No growth	Do.

Mark of the strain	Agar colonies	Medium for detection of formation of H.S.	Gelatine colony
R_1	Round grayish colony and crenate margin	H_2S is formed	White circular colony changing to creamy white
R_2	Small, round and gray colonies	Do.	Do.
R_3	Round white raised colony	H_2S is not formed	Filamentous with irregular margin
R_4	Do.	Do.	Circular white colony, entire
R_5	Round spreading entire	H_2S is formed	Circular, grayish, granular margin
R_6	White circular colony with sharp margin	H_2S is not formed	Small, white, dot shaped
R_7	Green, round, and raised colony. Medium turns brown	Do.	Round, greenish colony medium turns brown

Common characteristics: Motile, and do not form indole in peptone-water medium even when incubated for seven days.

TABLE IIB

Aerobic bacteria

Mark	Nutrient broth medium	Gelatine stab incubated at 20°C	Blood serum medium; 7 days incubation	Glucose medium	Fructose medium	Galactose medium
R_1	Turbid, pellicle formation	Liquefied	Liquefied slightly	Acid	Acid	Acid
R_2	Turbid	Do.	Do.	Acid and gas	Acid and gas	Acid and gas
R_3	Turbid, pellicle formation	Do.	Do.	Acid	Acid	Acid
R_4	Do.	Do.	Non-liquefaction.	Do.	Do.	Do.
R_5	Do.	Liquefaction	Liquefied	Do.	Do.	Do.
R_6	Turbid	No liquefaction	No liquefaction	Do.	Do.	Do.
R_7	Do.	Liquefaction	Liquefied	No growth	No growth	No growth

Mark	Xylose medium	Maltose medium	Lactose medium	Sucrose medium	Raffinose medium	Dextrin medium	Salicin medium	Inulin medium
R_1	Acid	Acid	Acid	Acid	Acid	Acid	Acid	Acid
R_2	Acid and gas	Acid and gas	Acid and gas	Acid and gas	Acid and gas	Acid and gas	Acid and gas	Acid and gas
R_3	Acid	Acid	Acid	Acid	Acid	Acid	Acid	Acid
R_4	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.
R_5	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.
R_6	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.
R_7	No growth	No growth	No growth	No growth	No growth	No growth	No growth	No growth

Mark	Arabinose medium	Mannose medium	Glycerol medium	Jute stem medium	Name of the bacteria according to Bergy's *Manual of Determinative Bacteriology*
R_1	Acid	Acid	Acid	Retted within 6 weeks	*Bacillus subtilis*
R_2	Acid and gas	Acid and gas	Acid and gas	No retting within 10 weeks	*Bacillus aerosporus*
R_3	Acid	Acid	Acid	Do.	*Bacillus cerus produces yellow* greenish fluorescence in all media
R_4	Do.	Do.	Do.	Do.	*Bacillus ruminatus*
R_5	Do.	Do.	Do.	Retted after 6 weeks incubation at 30°C.	*Bacillus mesentericus*
R_6	Do.	Do.	Do.	Retted after 6 weeks incubation at 35°C.	*Bacillus macerans*
R_7	No growth	No growth	No growth	No retting within 10 weeks at 20-25°C	*Pseudononas pavanacea*]

F1, F2, F3 and F4. F1 and F2 belong to the *Penicillium* group, F3 to *Mucor* group, and F4 to *Aspergillus* group. They are unable to ret jute stems in the jute stem medium when the stems are submerged in 2 to 3 in. of water, but if the jute stems are just made to lie on water without being submerged, then the strains marked F2 can ret jute stems in the jute stem medium in 25 days at 30°C.

Discussion

In the present investigation on the microflora of jute retting pit, five strains of facultative anaerobic bacteria belonging to the *Clostridium* group, eight strains of aerobic bacteria (of these six strains belong to the *Bacillus* group, one to the *Pseudomonas* group, and one to the *Thiobacillus* group) and four strains of fungi (of these, two strains belong to the *Penicillium* group, one to the *Mucor* group, and one to the *Aspergillus* group) have been isolated during actual jute retting.

The strains N1 and N2 belonging to the *Clostridium* group differ from *Clostridium felsiniae* [Bergy, 1934] only in their inability to grow in cellulose medium, otherwise both of them have the same characteristic as that of *Clostridium felsiniae*. The strains N_1 and N_2 differ from each other (*a*) in their physical shapes, (*b*) in their growth on potato slant, and (*c*) in their capacity to ret jute stems. The strain N1 rets jute stems in the jute stem medium in 14 days whereas the strain N_2 rets jute stems in 24 days under identical conditions. (Table I.)

The strains N_3 and N_5 belonging to the *Clostridium* group differ in their physical shape and in their jute retting capacity. The strain N_5 is very active in retting jute stems, whereas the strain N_3, though it grows well in jute stem medium, is unable to ret jute stems. The strain N_5 rets jute in 15 days. The strain N_4 is identical with *Clostridium mucosum* and does not ret jute stems. It is therefore evident that the strains N_1 and N_5 are the active organisms in jute retting. Of the aerobic bacteria isolated, *B. macerans* and *B. mesentericus and B. subtilis* (Table II) ret jute stems in jute stem medium, though very slowly as compared to strains N_1 and N_5. They take about $1\frac{1}{2}$ months for the completion of the retting process, under the same conditions. Adati and Yoshimura [1939] isolated 11 strains of aerobic bacteria from jute retting solution. They did not study the effect of their growth on jute stems. In our investigations, we have found that three of the aerobic bacteria stated above are capable of retting jute. *Bacillus carchorus* isolated by Katagiri and Makahama [1940] is stated to be very active in jute retting. But in the present investigation among the isolated organisms belonging to the bacillus group it has been found that none has got the characteristics of *B. corchorus*. But the strains of the isolated facultative anaerobic bacteria belonging to the *Clostridium* group have got the jute retting capacity of the *B. corchorus*.

Of the fungi isolated, only one strain marked F_2 can ret jute stem only when the jute stems are made to just lie on water for 25 days at 30°C.

Summary

The microflora of the jute retting processes has been investigated. Five strains of facultative anaerobic bacteria, eight strains of aerobic bacteria, and four strains of fungi have been isolated from jute retting pit. They have been characterized and their capacity for retting jute stems have been studied. Two strains of facultative anaerobic bacteria belonging to the *Clostridium* group have been found to be active micro-organisms for jute retting.

Acknowledgements

My best thanks are due to Dr. B. C. Guha, Ph. D., D.Sc. (Lond.), F.N.I., and Dr. B. N. Ghosh D.Sc. (Lond.), F.N.I., for their valuable suggestions and keen interest taken during the progress of the work.

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A STUDY OF THE RELATION OF CERTAIN MORPHOLOGICAL AND FUNCTIONAL CHARACTERS TO THE STEM RUST RESISTANCE OF WHEAT VARIETIES

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(Received for publication on 28 June 1946)

(With four text-figures)

To account for the differences in the capacity of wheat varieties to resist rust attack, various explanations have been put forward from time to time: these may be conveniently grouped under the two heads, physiological or biochemical, and mechanical or structural, the latter including such factors as hairiness of the leaf and leaf-sheath, the bloom or waxy coating of leaves and stems, the number and size of stomata, the time and duration of opening of stomata, and the amount and distribution of sclerenchyma and collenchyma in the culms. Some or all of these factors have been held, from time to time, to be correlated with the rust resistance of wheat varieties, especially of those which exhibit a high degree of what is termed as field or adult resistance. As the establishment of a definite correlation between rust resistance and some simple morphological or functional character would obviously be of great value in wheat breeding for rust resistance a study of such characters in relation to stem rust resistance in a number of representative wheat varieties was undertaken as an ancillary part of the programme of work of the Wheat Breeding Scheme* located at Simla, the main purpose of which is the breeding of rust-resistant wheat varieties. Although the data are not very extensive, it has been deemed desirable to place the results on record as such studies under Indian conditions have not been reported previously.

Survey of recent literature

The previous literature on the subject of rust resistance in wheat, including the possible role of morphological and other characters has been reviewed exhaustively by Hart [1931] and later by Brown [1936] and Wingard [1941]; therfore only papers dealing with the specific problem under investigation are surveyed here. Other relevant papers, however, will be referred to, when discussing the results of our experiments and observations.

Hursh [1924] after studying a large number of morphological and physiological factors which could possibly be responsible for rust resistance, such as hairiness of the leaf, the number, size and movements of the stomata and the distribution of sclerenchyma and collenchyma in the culms came to the conclusion that the latter could be correlated with rust resistance. This he considered was due to the fact that the rust fungus can live only in the chlorenchyma and as the only chlorenchymatous tissue in the wheat stem is the collenchyma, varieties possessing large amounts of sclerenchyma in their stems offer mechanical limitation to the spread of the invading mycelium and are therefore comparatively rust-resistant. Hart [1931] also found some evidence in support of the view that there is a correlation between rust resistance and the proportion of collenchyma present in the culms, at least as far as different varieties of the same species are concerned. She was at the same time of opinion that morphological resistance is not influenced so much by the proportion of the collenchyma in the stem as by the disposition, size and shape of the collenchya strands. Since then little work seems to have been done on this very interesting subject of mechanical resistance to rust infection.

With regard to the role of the stomata in relation to rust infection, some of the earlier researchers were of opinion that small size of the stomata might contribute towards varietal resistance. Hursh [1924] however came to the conclusion that stomatal apertures in probably all varieties of wheat are sufficiently large to permit the entrance of urediniospore germ-tubes. Further, working with a large number of varieties, he did not observe any large differences in the number of stomata found in these varieties. Amongst the varieties studied, Kota always had the least and Khapli the largest number, but the stomatal frequency was in no way correlated with the rust reaction of the varieties concerned. Hursh accordingly remarked that 'what appears to be more pertinent to the problem is the frequency and the extent to which stomata open.'

*Financed by the Imperial Council of Agricultural Research.

Working on this suggestion, Hart [1929] studied stomatal behaviour of several wheat varieties and their effect on rust infection in the field and green house. She reported that germ-tubes of *Puccina graminis tritici* usually do not penetrate closed stomata and the types of stomatal behaviour are characteristic for varieties of wheat. In some varieties stomata respond rapidly to favourable stimuli and open almost immediately after sunrise, in others they open very slowly or not at all. In the first case the fungus enters its host readily but in the second case, many of the germ tubes are excluded and the host is rarely infected.

According to her, the field resistance of certain varieries of wheat may be accounted for on the basis of their stomatal behaviour.

Petersen [1931] however was not able to verify Hart's results from his studies on H.44 and six other varieties. He found that environmental conditions such as light intensity played a more important part in the opening and closing of stomata than the varietal differences. He also quotes Brown's [1917] experiments in support of his view that the rust fungus readily infects wheat through closed stomata if the inoculation period is somewhat longer than in the experiments of Hart. This view he further strengthend by his own experiments. According to him, there were some differences in stomatal behaviour in the standard varieties but these did not seem great enough to account for differences in rust infection and some of them were not in accord with the functional resistance theory.

Caldwell and Store's [1932] results also tend to give a place of minor importance to the role of the stomatal openings in the physiology of fungal infection. They reported that the formation of an appresorium over an open stoma apparently stimulates it to close tightly but the the closed stoma offers no impediment to penetration. They observed this in the case of *Puccinia triticina* as well as *Uromyces fallens*.

It is however one thing for the open stoma to close under the stimulus of fungal appresoria and before the closing is complete allow the germ tube to gain entrance through the partially open slit (which is probably what actually happens), and quite another thing for the totally closed stoma to open up under this stimulus and allow an easy passage to the germ tube. Until that is proved conclusively, closed stomata will continue to be regarded as at least a partial impediment to the entrance of fungal hyphæ, especially in mature healthy plants growing in the field and possessing a well-developed cuticle.

Support is lent to this view by Allen's [1926] observations regarding the infection of *Puccinia triticina* on wheat in the early stages of infection. She found that in material fixed in the morning, many of the germ tubes had just entered the host and formed the substomatal vesicles; in the material fixed in the afternoon, the infection was always more advanced. She suggested that this daily rhythm might be due to the fact that entrance of the germ-tubes waits upon the natural opening of a stoma rather than upon mechanical force or chemical action.

The present investigation was undertaken to find out, under the conditions prevailing in the Simla hills, how far attributes such as the relative proportions and disposition of sclerenchyma and chlorenchyma, and also differences in the time, duration and amount of opening of stomatal apertures might be able to account for the varying degrees of field resistance to stem rust, in the set of wheat varieties selected for the study.

Material and methods

Material

The followig varieties, belonging to four species, were taken for study :

1. Varieties possessing a high degree of field resistance to stem rust :
   - *T. vulgare* / E. 144, E. 220
   - *T. dicoccum* / Khapli
   - *T. monococcum* / Einkorn
2. Varieties possessing a moderate degree of field resistance to stem rust ;
   - *T. vulgare* / I.P. 4, I.P.120, I.P.165, Webster
   - *T. durum* / Acme, Kubanka
   - *T. dicoccum* / Vernal

3. Varieties possessing little or no field resistance to stem rust.

T. vulgare : Agra Local, Simla 38, I.P. 101, Punjab 8A and Marquis.

For the stomatal studies, only eleven of the above were used.

The varieties were sown at the normal sowing time in small plots, replicated four times, on soil of average fertility ; sowings were also made in pots, there being four pots carrying five plants each, for each variety. The studies were carried out in 1939-40 and repeated in the following year.

Methods

1. *Studies of stem tissues.* For the sake of uniformity, it was decided to take for study only the first tiller of a plant at the heading stage, approximately 10 to 20 days after the spike had completely emerged from the sheath, when the peduncle was about 4 in. above the flag leaf.

The first point to be determined was which part of the culm was the most suitable for study from the point of being most uniform for the anatomical characters under consideration. For this purpose, tillers from a number of plants of several varieties were taken and sectioned at three places, viz. the peduncle region, the lowermost internode, and the middle internode, and the sections compared in regard to intra and intervarietal variation of internal structure of the stem. It was found that, as previously pointed out by Hursh [1924] and by Hart [1931], the peduncle showed the least amount of variation from plant to plant and that the percentage of collenchyma in the subepidermal regions in this part was remarkably constant for the variety under the same conditions of growth. It was therefore decided to take the region 1-2 in. below the rachis as typical of the variety for the purposes of the present study. Following Hart the proportion of collenchyma to be determined was taken as the 'percentage of the tissue facing the periphery of a circle superposed on a cross section of the peduncle'. This method of measurement takes into account only the face of collenchyma strands adjacent to the periphery and does not consider the size or configuration of the strands. For a comparative examination of these latter points, two other criteria were studied, namely, the number of single and double strands (Table I) and the width of the strands beneath the periphery and at the point of maximum expansion (Fig. 1, *a* and *b*). About 40 samples of each variety (10 from each replication), were taken in 1939-40 and the percentage of collenchyma determined. For preliminary study, sections were cut free-hand and slightly stained with iodine. This clearly brought out the chlorophyllous areas. Later, microtome sections were cut, 20μ thick and stained with safranin and light green. Sclerenchyma is thereby stained bright red, in contrast with the chlorenchyma which is stained green. Measurements were done with the help of a micrometer ocular under the low power of the microscope. About 10 further samples of each variety were taken in 1940-41 and examined in similar way for the confirmation of the previous results, so that, in all cases, the results given are based on observations of about 50 samples from each variety.

2. *Studies on stomata.* Both the chief methods for studying stomata, namely the method of examination *in situ* and the strip-leaf method were at first used in the study in order to determine their comparative merits. The first, as described by Loftfield [1921], consists in drawing the leaf across the microscope, clamping it lightly between the slide and cover-slip and examining the stomatal apertures while the leaf is still attached to the plant.

The second method extensively used by Lloyd [1908], consists in stripping pieces of epidermis from the leaf and rapidly immersing them in absolute alcohol. This reagent dehydrates the cell wall and hardens it so that it immediately becomes rigid ; hence the guard cells retain their shape and the stoma its degree of opening.

Examination *in situ* was done as described above except that it was not found necessary to clamp the leaf between the slide and the coverglass. Instead, the leaf was merely drawn across the stage of the microscope, lightly held in position by the slide clamps, and the degree of stomatal opening examined under the low power of the microscope. In this condition, focussing was easily accomplished without the use of the finer adjustment [Peterson, 1931] ; the use of slides and cover glass is only necessary for measuring the absolute value of stomatal apertures.

In the strip-leaf method, the precautions recommended by Loftfield were taken. It was observed that, properly used, both the methods give almost identical results. The direct observation

method, being easier and better suited for field study, was therefore followed in these studies. Moreover as observed by Loftfield it is preferable to other methods because it causes the least amount of disturbance to the stomata.

Following Peterson, the upper surface of six leaves of each variety, of approximately the same age, was examined and they were classified, with regard to stomatal opening to express the degree of stomatal opening; five classes were used, viz. (1) closed, (2) very slightly open, (3) slightly open, (4) half open, and (5) wide open. While 1, 3, 4 and 5 only have been used by Hart, and later by Peterson, it was found quite easy to distinguish class 2 from class 3. The second class, i.e. very slightly open, indicates the state of a stoma when it just starts opening. In all cases observations were taken only on mature healthy leaves in a state of normal turgidity. The leaves examined were illuminated by direct light from above only, the reflector on the microscope not being used. Under these conditions when a stoma opens slightly, the opening appears as a dark slit in marked contrast to the lighter coloured guard cells. The first observations were made in the morning sometime before sunrise and repeated after every 20 minutes till the stomata were seen to have opened fully.

The majority of observations were taken in April when most of the varieties reach the adult stage and when the temperatures are most favourable for stem rust infection at Simla. To eliminate differences that might arise due to different stages of growth of the various varieties two sets of observations were taken, one in the beginning of the month and the other towards its end.

To see the effect of low temperature and of cloudy weather etc. two other sets of observations were also taken in January, one in fine weather and the other in cloudy weather.

Experimental results

1. *Studies of stem tissues*

(*a*) *Proportion of collenchyma in the stem.* The relative proportions of collenchyma in the peduncle, as determined by the method described in the preceding section, in the 16 varieties studied are shown in Table I.

Table I

Proportion of collenchyma expressed as a percentage of the tissue facing the periphery of the stem, in sixteen varieties of wheat

Variety	Collenchyma percentage	Standard error	Variety	Collenchyma percentage	Standard error
1 E. 144	59·5	±0·48	9 I.P. 101	60·0	±0·38
2 E. 220	56·3	±0·33	10 Punjab 8A	59·3	±4·48
3 I.P. 4	53·7	±0·33	11 Marquis	59·5	±0·47
4 I.P. 120	58·3	±0·40	12 Acme	62·3	±0·52
5 I.P. 165	53·5	±0·38	13 Kubanka	62·6	±0·47
6 Webster	57·2	±0·44	14 Khapli	51·2	±0·51
7 Agra Local	60·9	±0·61	15 Vernal	56·8	±0·47
8 Simla 38	60·0	±0·54	16 Einkorn	50·4	±0·59

It will be seen that the smallest proportion of collenchyma is found in Einkorn and Khapli: the next smallest proportion is found in I.P. 165 and I.P. 4, followed by E. 220, Vernal and Webster; the remaining varieties have the highest proportion of collenchyma, especially the two *durum* varieties Acme and Kubanka.

Considering the *vulgare* varieties first, it can be said that whilst all the susceptible varieties studied have been found to possess relatively high percentage of collenchyma, the converse has not been found to hold true. Thus E. 144, a highly resistant variety, shows a percentage of 59·5, a figure as high as that shown by some very susceptible varieties such as Punjab 8A and Marquis; the other highly resistant *vulgare* variety, E. 220, shows 56·3 per cent, a comparatively high proportion,

Taking all the varieties together, it should be pointed out that the difference between the ones with the highest and those with the lowest percentages of collenchyma is of the order of about ten per cent only, and it is doubtful whether the sharp differences between the highly rust-resistant and the highly susceptible wheats can be explained on such small differences in the proportions of collenchyma present in the stem.

(*b*) *Relative numbers, size and disposition of collenchyma strands.* The size and shape of collenchyma strands and their disposition within the sclerenchymatous sheath was studied next. For this purpose, the average number of single and double or composite bundles present in the peduncle regions of the several varieties and the ratio of single to double was calculated. According to Hart [1931], varieties with a large number of double or composite bundles are more disposed to produce large confluent rust pustules, that is to say, they are liable to a greater degree of rust attack. The results are given in Table II.

It was observed that although the average number of single and double bundles in the varieties is rather variable, the ratio of single to double bundles does not vary greatly and may be taken being quite constant for each variety.

Two other values, namely, the tangential width of the collenchyma strands at the periphery i.e. in the subepidermal regions, and at the point of their maximum lateral expansion in the hypodermal region were also calculated. The figures obtained are summarized in Table III.

TABLE II

Proportions of single and double strands of collenchyma in the peduncle region of the wheat varieties studied

Variety	Average number of collenchyma strands		Ratio	
	Single	Double	Single	Double
1. E. 141	18	10	1·8	: 1
2. E. 220	21	7	3·0	: 1
3. I.P. 4	22	5	4·4	: 1
4. I.P. 120	18	6	3·0	: 1
5. I.P. 165	22	6	3·7	: 1
6. Webster	28	6	4·7	: 1
7. Agra Local	8	12	0·7	: 1
8. Simla 38	28	7	4·0	: 1
9. I.P. 101	9	13	0·7	: 1
10. Punjab 8A	12	10	1·2	: 1
11. Marquis	16	18	0·9	: 1
12. Acme	13	18	0·7	: 1
13. Kubanka	24	15	1·6	: 1
14. Khapli	14	6	2·3	: 1
15. Verhal	14	8	1·7	: 1
16. Einkorn	16	3	5·3	: 1

TABLE III

Average (tangential) width of collenchyma strands in μ at the periphery in the subepidermal region, and at the point of maximum tangential expansion in the hypodermal region of the peduncle, in the wheat varieties studied

Variety	Average (tangential) width of collenchyma strands in the			
	Subepidermal region	Standard error	Hypodermal region	Standard error
1. E. 144	112·5	±1·17	193·3	±1·45
2. E. 220	91·1	±0·95	158·5	±1·22
3. I. P. 4	88·5	±1·34	123·0	±1·26
4. I. P. 120	86·4	±1·21	124·8	±1·10
5. I. P. 165	89·5	±1·19	130·6	±1·16
6. Webster	111·1	±0·71	142·5	±1·71
7. Agra Local	103·5	1·23	155·0	1·30
8. Simla 38	114·2	±1·12	163·0	±1·06
9. I. P. 101	88·0	±1·13	118·0	±1·22
10. Punjab 8A	112·4	±1·06	138·4	±1·75
11. Marquis	116·1	±1·44	167·1	±0·98
12. Acme	117·4	±1·34	184·5	±1·67
13. Kubanka	110·3	±1·22	176·2	±1·48
14. Khapli	83·0	±0·78	124·7	±1·16
15. Vernal	88·9	±0·89	141·7	±1·46
16. Einkorn	80·3	±0·76	114·0	±1·23

In Table II, it is seen that Agra Local, I. P. 101 and Acme, (the first two, highly susceptible varieties and the third, a moderately susceptible one) have the greatest number of double strands: they are followed by Punjab 8A and Marquis, again highly susceptible varieties. Varieties with a larger proportion of single strands than double, include the resistant varieties, Einkorn, Khapli and E. 220, the moderately susceptible ones such as Webster, I. P. 165, I. P. 4 and I. P. 120 as well as the susceptible variety Simla 38. There is therefore no clear association between the relative numbers of single and double strands, and resistance or susceptibility of the varieties concerned.

As regards the characters studied and summarized in Table III, comparatively wide strands are found to occur in resistant varieties as well as in susceptible ones: the group of varieties with relatively narrow strands similarly includes both resistant and susceptible forms. These characters too, therefore, have no association with the rust resistance of the varieties concerned. It was observed that, generally early-maturing varieties had smaller collenchyma strands than varieties with a comparatively longer period of growth.

In view of the above it seems doubtful if the characters studied can be utilized as indices of rust resistance, in breeding work.

2. *Studies on stomata*

The results of the observations taken are represented in Figs. 1-4, each chart embodying the results of observations taken for at least a week, except Fig. 2 which records the observations taken on two typically cloudy winter days only.

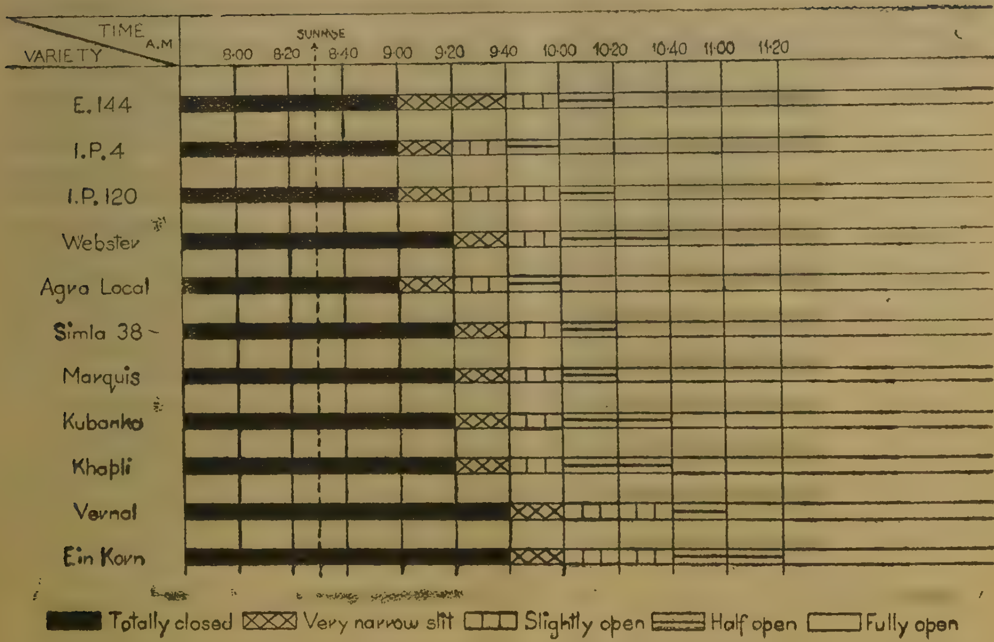

FIG. 1. State of stomatal opening on a fine day in mid-winter—Results of observations from 3 to 10 January 1941

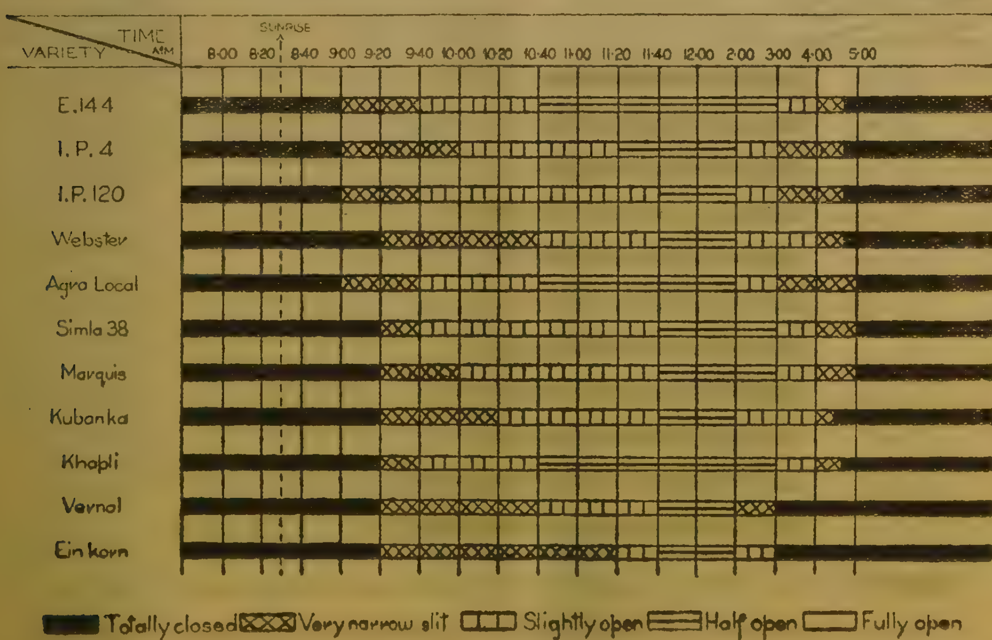

FIG. 2. State of stomatal opening on a cloudy day in mid-winter—Results of observations on 14 and 15 January 1941

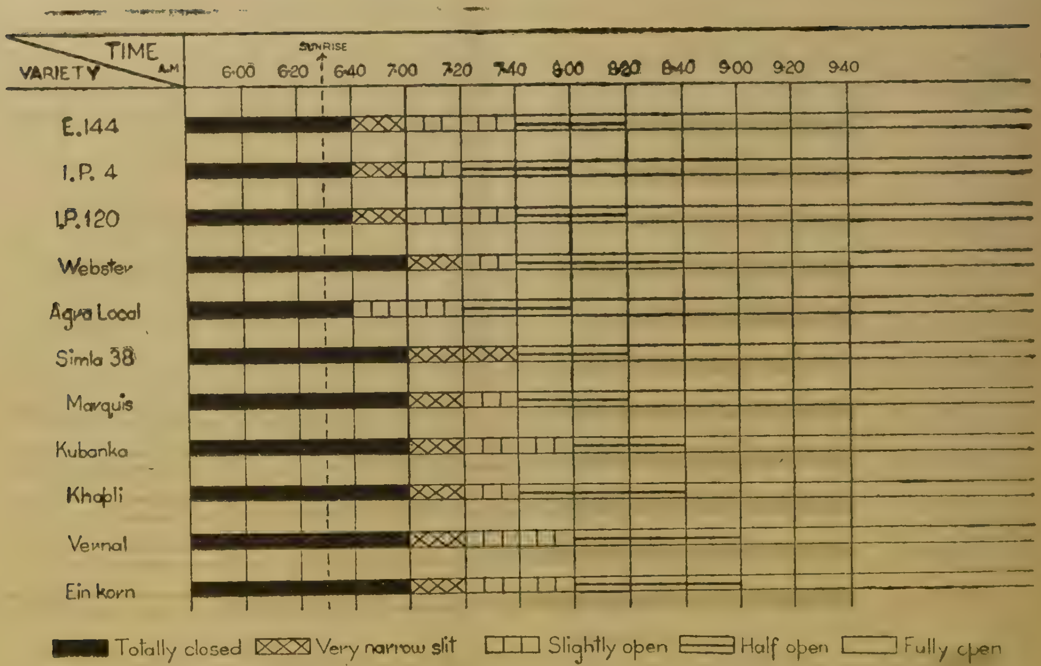

FIG. 3. State of stomatal opening on a fine day in early spring—Results of observations from 1 to 8 April 1941

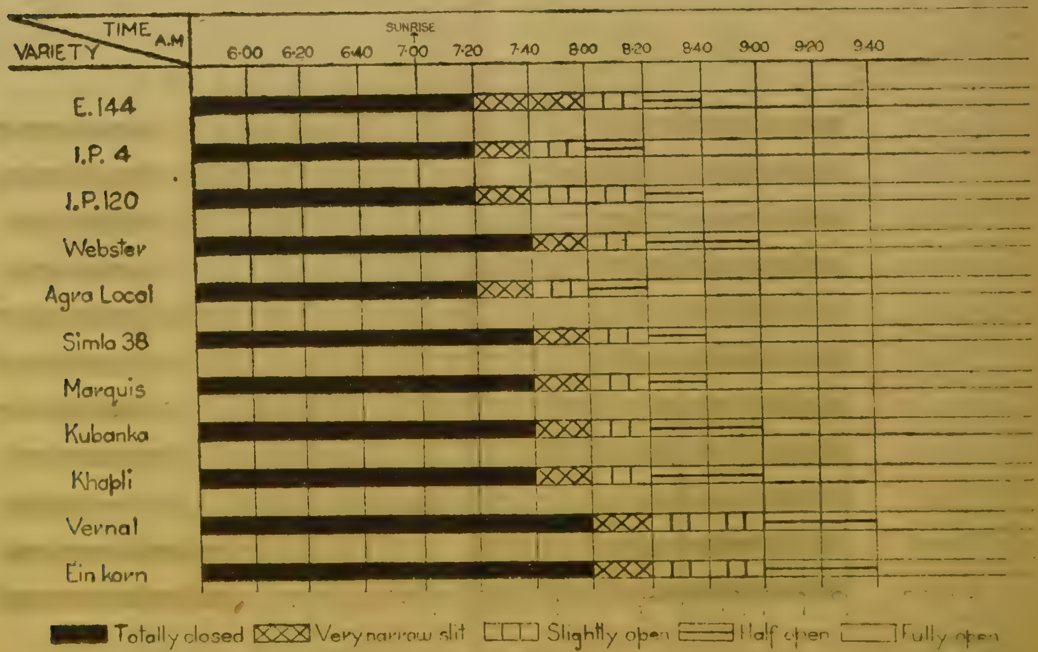

FIG. 4. State of stomatal opening on a fine day in mid-spring—Results of observations from 23 to 30 April 1941

Analysis and discussion of results

The first point which emerges from the study is the remarkable daily rhythm exhibited by the stomatal movements in all the varieties, a phenomenon first pointed out by Loftfield. Thus on a fine spring day such as that of April and May at Simla the stomata in all cases open sometime after sunrise, remain wide open for five to eight hours, depending upon the variety but even more on conditions of atmosphere, humidity, solar insulation and soil moisture, after which they slowly start on the closing trend and are completely closed by the evening. The closing stages, however, have not been shown in the figures as being not quite relevant to the problem of rust infection, because in all cases the stomata were always found closed by the time the period of dew formation started in the evening.

As will be evident from the figures, the varieties were found to exhibit appreciable differences as regards the time and consequently the duration of stomatal openings in the mornings, under the same optimum conditions of light, temperature and soil moisture, etc. The last factor was found to be of considerable importance, second only to light in this respect. Thus in certain observations made with pot-sown plants where soil moisture was deficient, the stomata were found to behave rather erratically, not conforming to the typical behaviour of the varieties. Such sets of observations have not been included in the results. For the stomata to open normally, it is essential that along with sufficient light, there should be enough of moisture in the soil.

Another point worth mentioning is the very slow rate of the opening of stomata observed in these experiments. Thus while in Hart's experiments [1929-1931] stomata were fully open in some cases within 80 minutes of the sunrise, in the present experiments, stomata take at least about 90 minutes to reach that stage in varieties possessing early-opening stomata. This probably is due to the comparatively lower temperatures prevailing at this experimental station.

On the basis of Fig. 4 we can classify the varieties studied as possessing early, mid-early, late- and very-late-opening stomata. The varieties are classified below into these various classes :

Varieties with early-opening stomata (stomata fully open in about 110 minutes after sunrise in mid-spring) :

E. 144, I. P. 120, Marquis, Simla 38.

Varieties with late-opening stomata (stomata fully open in about 130 minutes after sunrise in mid-spring) :

Webster, Kubanka, Khapli

Varieties with very late-opening stomata (stomata fully open in about 150 minutes after sunrise in mid-spring) :

Vernal, Einkorn

Observations recorded in Fig. 3 regarding the stomatal movements of these same varieties in early spring, i.e. about the beginning of April are in substantial agreement with the above classification. It will be seen that although there are appreciable differences in the time of stomatal opening as observed in early, and mid-spring, the differences are mainly related to the time of sunrise, the openings in all cases being earlier in mid-spring than in early-spring. The varietal differences however observed in the one set are found to exist in the other set also, early-opening varieties being early here also and vice versa.

Fig. 1 records observations on the same varieties in mid winter, i.e. the first week of January. Here also similar varietal differences are exhibited, although the time and duration of the stomatal opening at this season are naturally very different from what they are in spring.

Fig. 2 records the state of stomatal opening on a typical cloudy day of winter when dense clouds prevailed throughout the day. Here we find that because of insufficiency of light, the stomata did not open widely at any time of the day. From about 11 A.M. to about 3 P.M. the stomata generally remained in a half open state and then started closing down. Even here, however, varietal differences in the stomatal behaviour are discernible and evidence the same trend as the other sets of observations.

Taking all these into account we are probably justified in concluding that the time, and as such, the duration of the opening of stomata in the mornings, is a varietal characteristic, the differences occurring between different varieties studied being sometimes as much as an hour or more. The

differences however do not seem significantly correlated with the rust reactions of the varieties concerned. Thus I. P. 4, a variety possessing only a moderate amount of field resistance, has got early-opening stomata like Agra Local, one of the most susceptible varieties. E. 144, one of the most resistant varieties to Indian races of black rust, on the other hand, has mid-early-opening stomata resembling in this respect two of the susceptible *vulgare* varieties, Marquis and Simla 38.

Although species other than *vulgare* are represented by a few varieties only, it would appear that in all these stomata open comparatively later than in varieties belonging to the *vulgare* species.

What can be stated with a greater amount of certainty is that varietal differences in stomatal movements seem to be associated with, and might be regarded as an index of, other and more important ecological and physiological differences existing in the varieties concerned. One of the more important of such differences appears to be the growth habit of varieties, as early-maturing varieties generally seem to possess early-opening stomata and conversely in the late-maturing ones the stomata generally open late. It is well known that varieties exhibiting the same or similar reactions to rust might belong to widely-different ecological groups and differ greatly in their physiological behaviour in other respects. It would similarly appear that the association of a particular type of stomatal behaviour with a definite type of rust reaction of varieties such as the association between late-opening stomata and resistance to rusts, wherever it is found to exist, must be regarded as incidental only, although the presence of such an association might contribute towards an increase in varietal resistance.

Summary

Sixteen wheat varieties belonging to the species, *T. vulgare*, *T. durum*, *T. dicoccum* and *T. monococcum* including varieties highly resistant, moderately resistant and highly susceptible to stem rust, were studied in respect of the proportion of collenchyma in the peduncle region of the stem, the relative numbers of single and double collenchyma strands, and the size of the individual collenchyma strands. While all the susceptible varieties were found to possess a comparatively large proportion of collenchyma, the reverse did not hold true and some of the resistant varieties also had a large proportion of collenchyma.

The time of opening of the stomata in the morning, and the duration of the period of opening, were studied in 11 varieties out of the 16 referred to above, at two periods in winter and two periods in spring. While the time of opening of stomata was found, within limits, to be a varietal characteristic, no correlation was discovered between this character and the rust reactions of the varieties studied.

It is concluded that none of the characters studied furnishes an index for facilitating the breeding of rust-resistant strains of wheat.

Acknowledgement

We wish to express out gratitude to Mr S. D. Misra for assistance in the course of these studies. We are also indebted to Dr S. Ramanujam and Dr B. S. Kadam for reading through the manuscript and making helpful suggestions.

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FIG. 1. Phulwa plant leaf with necrotic spots

FIG. 3. President leaf showing necrotic spots

FIG. 2. An advanced stage of foliar necrosis

FOLIAR NECROSIS IN POTATO VARIETY PHULWA

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(Received for publication on 28 March 1946)

(With Plate XXVIII)

With a view to establishing disease-free seed stocks of potato variety Phulwa in connection with the seed certification project, 51 apparently healthy and vigorously growing potato plants of Phulwa variety were selected from the crop growing in the experimental plots of the Mycological Division in the winter of 1944-45. Part of the seed material from each plant thus selected was grown in the insect-proof house in the winter of 1945-46 in order to test it for freedom from virus diseases. The plants so raised exhibited foliar necrosis three weeks after planting. A large number of Phulwa plants raised in the insect-proof house in the winter of 1941-42 also exhibited similar symptoms. From the point of view of selection of apparently disease-free material in the field, this appeared to be a serious problem as a major portion of the selected material had to be discarded. Tests were therefore conducted to determine the casual virus, as the affected portions when transplanted on agar medium failed to yield any organism.

Symptoms of disease. In potato plants of Phulwa variety necrotic spots are found scattered on both the young and old leaflets. Necrotic spots occur in considerable numbers in the lower portion of the plant and at times the upper portion of the plant may be entirely free from necrosis. The size of these necrotic spots as they appear varies ; these may be as small as pin points. Necrotic spots may be distributed over the surface of the leaflets and may be far apart each other or they may be very close to each other in which case, in due course, they coaleasce to form larger spots. The smallest leaflets soon after emergence may be entirely killed due to the appearance of necrotic spots, leaving behind only slight brown rudimentary structures.

The formation of necrotic spot starts with a faint mottle on the leaflet. The mottle in due course becomes pale and later on becomes dark brown. The necrotic spots are encircled by a faint ring of light coloured tissue which separates them from the green leaf tissue. The necrotic spots penetrate the thickness of the leaf and are well defined on the upper surface to begin with. The area surrounding the necrotic spots gradually dries up and becomes brown and even at this stage the necrotic spots can be easily distinguished. In advanced stages margins and tips of leaflets may begin to dry up and sometimes even the whole leaflet may dry up. Plate XXVIII, fig. 1 shows Phulwa plant leaf with necrotic spots ; fig. 2 shows an advanced stage of the disease.

Reactions on differential hosts. The reactions on differential hosts of the virus causing foliar necrosis were studied by transferring the extract from infected Phulwa potato plants to sets of differentials such as *Nicotiana tabacum* L. Vars. White Burley, German Samsun and Harrison's Special, *Capsicum annuum* L, *Datura Stramonium* L. and Potato Vars. President and Epicure. In addition, transmission by grafting was also done in certain cases. Inoculations were carried out by smearing the leaf with a piece of absorbent cotton wool dipped in freshly prepared standard extract from the diseased plants in the presence of finely powdered carborundum. All the experimental work was carried out in an insect-proof house.

The reactions on differential hosts are briefly described.

Nicotiana tabacum var. White Burley. The first symptoms of infection are observed on the inoculated leaf about 12 days after inoculation. To begin with the leaf shows faint circular mottle and 4-5 days later the circular mottle becomes more pronounced. The symptoms appear on other leaves in due course. In German Samsun faint circular mottle is observed at the tip of the leaf seven days after inoculation. The mottle gradually covers the entire leaf surface. The symptoms on Harrison's special are more or less similar to those on German Samsun but take a little longer to appear in the first instance.

Capsicum annuum. The first symptoms of infection, in the form of circular mottle, appear 15 days after inoculation. The mottle was more pronounced along and around the midrib.

Datura Stramonium. The plant showed general pallor in colour but no distinct mottle was observed.

Potato var. President. The President potato plant exhibited first symptoms of foliar necrosis about 15 days after inoculation, whereas the plant to which diseased scion had been grafted exhibited foliar necrosis after about one week. The necrotic spots were more numerous along the leaf margins and later coalesced to form larger necrotic areas. Plate XXVIII fig. 3 shows a leaf of President plant infected with virus.

Potato var. Epicure. The plant turned pale six days after inoculation and was killed in due course. The paling and necrosis started from the uppermost portion of the plant.

Transmission. The virus can easily be transmitted by mechanical means.

The symptoms on differential hosts indicate that the virus obtained from Phulwa plants showing foliar necrosis is *Solanum Virus* 6: a virus closely related to *Solanum Virus* 1. Potato varieties British Queen, Arran Cairn, Arran Chief, Arran Comrade, Arran Pilot, Katahdin, Edzell Blue, Mary Queen, Rhoderick Dhu, Sharpe's Express and Kerr's Pink are known to exhibit foliar necrosis as a result of infection with *Solanum Virus* 6, whereas varieties Epicure and Up-to-date show top necrosis. The occurrence of this virus has, however, not so far been recorded from India.

THE BIOLOGY AND CONTROL OF *PSEUDAULACASPIS PENTAGONA* (TARGIONI) PEST OF PEACH TREES IN THE KUMAUN HILLS

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(Received for publication on 28 March 1944)

(With Plates XXIX and XXX)

Peach trees in the Kumaun hills are attacked by two species of scale insects, *Lecanium* sp. and *Pseudaulacaspis pentagona* (Targioni). The former, though widely distributed all over the hills, is not a serious pest but the latter has caused considerable damage in all the orchards near about Ranikhet. This species is so far not known to occur in any other part of India except Assam, and in Kumaun also it is confined to orchards near Ranikhet. In case of severe infestation the tree presents a white appearance (Plate XXX, fig. 1) but when the insects are young and the coating of scale is not very thick on them, the infested branches appear yellowish white due to the bright orange yellow bodies of the insects being visible through the thin scales. Damage done to the tree is not noticeable in the beginning of the attack but constant drain of the sap interferes with proper growth and vigour, and eventually kills the tree. It is also not uncommon to find one or two branches of a tree very severely attacked while the rest of it remains quite clean.

Japan is said to be the original home of *P. pentagona* [Riley and Howard, 1894] whence it was probably imported into Australia where Tryon [1889] described it as *Diaspis amygdali*. it appears that there is some variation in the colour and the size of the insect in different countries and on different host plants. Its life history also differs in different localities. In North America and in Japan, for instance, it is said to be double brooded [Newstead, 1900, and Sasaki, 1894] though Riley and Howard [1894] observed that the female insect required eight to nine weeks for its full development and that there was a constant succession of broods throughout the year. In Kumaun there are four distinct broods in a year. Very probably due to foregoing reasons, the species has been described under different names, viz. *Pseudaulacaspis pentagona* (Targioni), *Diaspis pentagona* (Targioni), *Diaspis amygdali* (Tryon), *Aulacaspis pentagna* (Targioni), *Diaspis lanatus* (Morgon and Cockerell), and *Diaspis patelliformis* (Sasaki).

Distribution and food plants

P. pentagona is a very widely distributed species having been known from Japan, Australia, Trinidad, Jamaica, Southern Europe, England and America on such unrelated host plants as mulberry

LIFE-HISTORY OF *PSEUDAULACASPIS PENTAGONA* (TARGIONI)

FIG. 1(*a*). Female puparia natural size *in situ* on peach twig.
FIG. 1(*b*). Male puparia natural size *in situ* on peach twig.
FIG. 2. Puparium of adult female, dorsal view × 10.
FIG. 3. Puparium of adult female, ventral view × 10.
FIG. 4. Ova × 30.
FIG. 5. Newly hatched larva × 40.
FIG. 6. Larva after first moult × 17½.
FIG. 7. Puparium of female a few days after second moult × 10.
FIG. 8. Female at period of gestation × 12½.
FIG. 9. Female about to deposit eggs × 12½.
FIG. 10. Adult female after treatment with potash × 20.
FIG. 11. Pygidium of adult female × 100.
FIG. 12. Puparium of young male × 12½.
FIG. 13. Male pupa × 12½.
FIG. 14. Empty puparium of male × 12½.
FIG. 15. Adult male × 30.

FIG. 1. A portion of a peach tree badly infested with *P. pentagona*

FIG. 2. Two varieties of peach trees, I. Carmen (susceptible)
II. Gladstone (resistant)

papaya, lilac, fig, poplar, walnut, etc. It has been observed on *Cedrella toona*, in addition to peach, in Kumaun and on cherry at Shillong (Assam). In Ceylon its hosts are recorded to be Erythrina sp., peach, *Callicarpa lanata*, *Tylophora asthmatica*, geraniums and *Heliotropium sp.*

Economic status in Kumaun hills

P. pentagona is mostly confined to small, neglected orchards near about Ranikhet. In this locality a large number of peach trees are killed by the pest every year. Although it may remain confined to certain branches of a tree for a number of years, it is not uncommon to find trees almost covered with the scales from top to bottom. Riley and Howard [1894] believed that plants that are sheltered from weather are specially susceptible to attack but it is not so in this locality. The tree in Plate XXX, fig. 1 stood at very exposed site with no other trees in the vicinity but many of its branches were completely covered with the scales. The pest is so far not well known to many of the orchardists in the Kumaun hills but there is little doubt that it may do serious damage in any year.

The attacked tree loses its vigour and the crop is affected both in quality and quantity. If remedial measures are not adopted, heavily infested trees or branches die in four or five years.

An examination of all the peach trees in the different orchards of Ranikhet was made in 1942 to determine the incidence of the pest and the data are presented in Table I from which an idea of its seriousness can be obtained.

TABLE I

Incidence of P. pentagona *in Ranikhet orchards (1942)*

Name of orchards	Number of trees.	Number attacked	Percentage of attacked trees	Intensity of attack				
				I	II	III	IV	V
Badri Lal	25	13	52	5	5	1	1	1
Manohar Lal	16	3	18·8	2	1	—	—	—
Keshab Datt	34	7	20·6	4	3	—	—	—
Fergusan	36	18	50	8	5	2	2	1
Company Bagh	13	4	30·8	2	1	1	—	—
Rustam	25	10	40	6	—	1	3	—
Bhola Datt	13	9	69·2	4	2	1	1	1
Shanker Lal	21	4	19·05	2	1	—	1	—
Shiva Lal	28	8	28·6	7	—	—	1	—
TOTAL	211	76	36	40	18	6	9	3
				18·9 per cent	8·5 per cent	2·9 per cent	4·3 per cent	1·4 per cent

I Less than 1/5 of the tree covered with the scales.
II 1/5 to 2/5 ,, ,, ,,
III 2/5 to 3/5 ,, ,, ,,
IV 3/5 to 4/5 ,, ,, ,,
V Almost fully covered with the scales.
N.B.—The figures under I, II, III, IV and V denote the number of trees attacked.

Susceptibility of peach varieties to *P. pentagona* attack

Observations during the last several years have shown that *P. pentagona* prefers certain varieties to others. In order to ascertain if any of the commercial varieties are resistant to the pest, three plants of each of the 18 important varieties grown in the Government orchard, Chaubattia, were potted in winter, 1938, and artificially infected with a large number of scale insects in April, 1939. The varieties included in the trial were :

Carmen, Crawford early, Crimson Galande, Royal George, Pergrine, Red Necterine peach, Alexander, Gross Mignonne, Alton, Elberts, Princess of Wales, High's Early Canada, Early Rivers, Amesdens' June, Duke of York, Condor, Stirling Castle and Gladstone.

Examination of the plants in October, 1939, showed that only plants of the first nine varieties were attacked by the pest. All the plants were again artificially infected in April, 1940, and examined in the following October. In the year following, Duke of York and Condor which remained free in 1939, were attacked along with the other nine varieties named above. Observations were continued in the third year also but no artificial infection was considered necessary as there were innumerable living insects on the 11 susceptible varieties and the unattacked plants were kept quite close to them. The remaining seven varieties, viz. Elberata, Princess of Wales, High's Early Canada, Early Rivers, Amesdens June, Stirling Castle and Gladstone remained unattacked in the third year also (Plate XXX, fig. 2.).

Description of various stages of *P. pentagona*

General description for recognition in the field

Infested branches look white or yellowish white. Female scale is convex, approximately circular or ovate with the cast skin placed towards the margin in front; in some specimens the exuviae may be placed slightly towards the centre. The colour may be white, yellowish, greyish or dusky white due to the fact that it is often mixed with the epidermal tissue of the bark of attacked trees. Scales (puparia) of younger females are generally oblong or pyriform with the cast skin situated at the extremity. Diameter of full grown female scale is 1·25-2 mm.

Male scale is snowy white, elongate and faintly carinated. It is attached to the bark by its anterior extremity with the hinder parts elevated. Ventral scale is also well developed. Length is 1-1·5 mm.

Males and females generally inhabit different portions of the same tree (Plate XXIX, fig. 1) but a few male puparia may be seen among the females

Technical description of the adult female

Green [1896] redescribed the adults of both sexes and their puparia and examinations made in Kumaun conform to his description except in a few minor details, such as, variations in colour and size. The specimens collected in Kumaun are smaller and brighter in colour than those examined by Green. From his description it appears that the full grown female attains a larger size in Ceylon which may be due to his having examined only the insects situated singly on the host plants where they get more space for the full development of their bodies than in crowded colonies.

The egg and the newly hatched larva have so far not been fully described although it is important for the orchardist to know and distinguish them. Their main characters are therefore given below.

Egg. Elongate oval; 0·25 mm. long and about half as wide. Colour mostly bright pink orange, or orange yellow; in about 5 per cent cases creamy white. A fine white powdery, waxy substance is often found adhering to the eggs. On maturity of the embroyo in the egg, the eye spots become distinctly visible from outside. The egg-wall is snowy white, thin, of membranous consistency and semi-transparent.

Newly hatched larva. Very active, flat, ovate; 0·25 mm. long and about $\frac{2}{3}$ as wide. Eyes distinct and abdominal segments discernable. Colour of antennae, legs, caudal setae, creamy white or pale yellow. Body colour same as that of the egg.

Sexual difference in the newly hatched larvae. Generally there are no marked sexual differences in the early stages of *Coccidae* but in *P. pentagona* the sexes can be distinguished immediately after the hatching of the eggs or even before that. The creamy white larvae develop into males and the pink orange ones into females. This becomes very evident soon after the first moult when the former start making elongate male and the latter circular female puparia. The cast skin retains the colour of the larva for quite a long time and, as it remains attached to the puparium, the fact can be verified at any time by examining puparia of both the sexes. In advanced stages the creamy white colour of the male exuvae gradually fades away and hence after some time they become quite invisible.

The exuvae of the female, however, remain quite distinct for a long time after their death. Sexes are not produced in equal proportion. About 95 per cent of the individuals of each brood are females.

Green [1898] also considered that differences in colour of the larvae were possibly sexual. His assumption that larvae of different sexes are produced at special periods is incorrect as in each brood the larvae of both the sexes are produced simultaneously. His views on the subject are quoted below :

> 'The newly hatched larvae are of two distinct colours, creamy white and bright pink ; the difference is possibly sexual. I find a similar difference in the colour of the eggs, some being pale yellow and others pale-pink ; the two forms being laid by distinct individuals. It seems probable, therefore, that special female or females at some special period, produce larvae of one sex only '.

Life history and habits

Oviposition. The female takes several days to deposit all her eggs and the egg-laying for a brood normally lasts for about 14 days. Eggs are laid beneath the scales and as the egg-laying proceeds, the body of the female gradually goes on shrinking upwards to make room for the eggs which are never deposited in exposed places. As the eggs are laid only in the space provided by the mother, egg-masses are mostly irregular. The number of eggs laid by a single female varies from 23 to 54 in crowded colonies but the average may be about 40.

Hatching. Eggs hatch 8-12 days after oviposition, depending on the season of the year. As all the eggs by the same female are deposited in several days, hatching also is continued for a number of days.

Habits of the larva. After hatching the larva remains under the parent scale for some time after which it comes out and wanders about actively on branches. On finding a suitable place, which it may get after 24 hours search, it settles down and inserts its thread-like probocis into the bark of the plant from which it draws its nourishment. After a short time it begins to exude fine threads of wax which form a fine film over the body.

First moult. After about eight days from the time of its settling down on the tree, the larva sheds its first skin and with it the antennae and legs are also shed. The young insect loses all organs of locomotion and becomes a grub-like creature. Only the mouth parts remain intact to enable it to draw nourishment from the plant. From this stage the development of the sexes differ. A waxy substance again begins to be secreted by the insects of both sexes which, in the case of male, forms an elongate complete puparium while, in that of female, only a thin circular covering which is cast off along with the skin at second moult.

Second moult. About 10-12 days after the first moult the female casts its skin for the second time. The second skin together with its covering of waxy substance is joined to the first and with it forms a part of the female scale. The insect grows considerably after the second moult and the greater part of the scale is also excreted after this moult.

Immediately after the second moult of the female the adult males emerge and fertilize the females. After fertilization the body of the female increases in size and gradually becomes extended with the development of eggs. Oviposition takes place usually three weeks after the second moult.

Thus the life cycle of the female is completed in about 8-9 weeks during the greater part of the year but in winter it is very much prolonged. Although the species has no resting season, the growth during winter, especially of the female after the second moult, is comparatively very slow. The eggs deposited in early October do not all hatch before the end of the month and the females of this brood start egg-laying towards the middle of February and continue till the middle of March.

Number of broods in a year. There are four distinct broods in a year in Kumaun. The time occupied by each brood (egg to egg) during a year (1941-42) is as given in Table II.

Table II shows that the time occupied by the winter brood is very much prolonged. There is no overlapping of the broods. Insects on the same variety of plants are always found to be of the same age but they may be in slightly different stages of growth on plants of different varieties. This difference is more marked in winter due, probably, to there being some difference in the times of suspension and resumption of activities in different varieties.

TABLE II

Time taken by different broods of P. pentagona during 1941-42

Serial No. of broods	Time taken			Average of maximum temperature during the period
	From	To	No. of days	
I	13-8-41	8-10-41	57	70 F.
II	9-10-41	14-3-42	157	58 F.
III	15-3-42	9-5-42	56	72°F.
IV	10-5-42	12-8-42	95	75°F.

Mode of dispersal. Like other Coccids, only the minute larvae of *P. pentagona* can migrate. After escaping from beneath the parent scale and before settling down on the host plant, the young larvae move about very actively in search of suitable places to settle down. In doing so, they can crawl to other trees also if the latter happen to be quite close to the infested tree. In this stage they can be carried from one place to another by birds, animals, human beings and other insects and can also be blown to long distances by wind. Although the chances of its spread in this stage appear to be great, the pest generally remains confined to the already infested trees for a number of years. This is mostly due to the fact that the active life of the insect is very short. It is unable to move after it has settled down on a plant and started feeding. The chief means of its dispersal from one part of a country to another, or even from one to another widely separated country, is through imported live plant material harbouring the young insect which can so easily be overlooked by even a careful orchardist due to the minute size of the larva and its inert nature. The occurence of the species in countries widely separated must have been brought about by this method.

CONTROL MEASURES

Method of preventing the spread of the scale insect

From the foregoing it would appear that the pest can be kept out of an orchard, not already infested by it, by careful watch. If possible an isolated spot should be selected for planting a new orchard and one should be very careful in importing live plant material from other orchards. As a precautionary measure, all the imported plants, buds, and scions should be washed thoroughly with a strong contact insecticide just on their arrival. The insecticide should be such as can destroy the insect without causing any injury to the plant material. Lime-sulphur or even a strong solution of soft soap can serve the purpose very well.

If, even after taking all necessary precautions, one comes across one or more branches of hitherto unattacked trees covered with white scales, he should immediately cut them off and burn them on the spot. The trees should be kept under constant observation and any other case discovered should be dealt with similarly. If it is found that the pest has established itself in the orchard and cutting and burning of the infested parts of trees is no longer practicable, the pest can be kept under control by spraying the infested trees with a suitable insecticide discussed hereafter.

There is a general belief that vigorous trees are less liable to become infested by scale insects than weakly growing trees and some also seem to think that the scale insects can be forced to leave an infested tree by stimulating its growth [Rilley and Howard, 1894]. The experience of the writer does not confirm these beliefs, at least so far as *P. pentagona* is concerned, on the contrary, the vigorous

growing tender shoots of a susceptible variety are preferred by the insect to unhealthy branches. The insect gradually deserts an unhealthy tree and leaves it altogether before it is dead. A healthy tree can, of course, withstand its attack better than the one already weakened by other causes.

Growing of resistant varieties

As far as possible only resistant varieties should be grown. If early, mid-season and late varieties can be selected from the list of commercially important resistant varieties, there is no point in having any of the susceptible varieties in the orchard. If, however, one is forced to grow one or more of the susceptible varieties, he should first of all try to keep them free of the pest by the above methods, failing which the infested trees should be sprayed by one of the insecticides recommended in this paper.

Use of contact insecticides

As the insect infests every part of a peach tree from the base of stem to the tips of twigs and is protected by a covering of scale, it is necessary that the whole tree must be given a very thorough wash with an effective insecticide by means of a force pump. The best time of spraying against this pest should be winter when the trees remain in dormant stage. At that time a strong solution can be used without fear of injury to the leaves and the leafless trees can easily be sprayed very thoroughly. A time should be chosen when the insects are young. This stage can easily be detected as the yellow bodies of the insects are visible through their semi-transparent scales and the infested branches present a yellowish white appearances.

Several contact insecticides have been tried against scale insects in the past by various workers and many of them have been discarded for one reason or another. From the list of the insecticides said to be very effective against scale insects, five were selected for trial at Chaubattia, taking into consideration their cost and the relative ease with which they may be applied.

Trial of scale insecticides at Chaubattia

Material and method. Six average sized peach trees were attacked by this pest in a small orchard near Ranikhet. In a few cases only one or two branches were affected, but mostly the attack was rather severe. As there was not enough material available for trying different insecticides on different portions of the same tree, each tree was given a separate treatment. There being thousands of living scales on each tree at the time of spraying and the trees being on the same soil and of the same age, the results obtained are fairly comparable. The insecticides used were as follows:

1. Kerosene oil emulsion :—Soft soap	1 lb.	Diluted with 10 parts of water for spraying
Kerosene oil	2 gallons.	
Water	1 gallon	
2. Fish oil rasin soap :—8 oz. to one gallon of water.		
3. Soft soap :—8 oz. to one gallon of water.		
4. Caustic soda wash :—Caustic soda	1 lb.	
Soft soap	1 oz.	
Water	10 gallons	
5. Lime sulphur (sp. gr. 1·318) :	1 part	
water	8 parts	
Untreated plant served as control.		

Soft soap was prepared in the laboratory with pure caustic potash and linseed oil.

The spray was applied by means of a hand manual machine, at a pressure of about 75 lb. per sq. inch on 5 December 1936. As the spraying was done after leaf-fall and there was no danger of any damage to leaves, a thorough wetting was given to all trees. This was the right time also for spraying as the insects were all in young stage.

Effect of different sprays

The trees were labelled for the different treatments and a piece of bark about one sq. inch in area was removed from each tree just before spraying. All the living and dead scales upon each piece were counted. As the following figures will show, all the scales were living except in one case where 10 p.c. were already dead before spraying. Due allowance was made for this while assessing the results.

Number of living and dead scales per sq. inch before spraying

Tree No.	I	II	III	IV	V	VI
Living	720	180	600	260	..	500
Dead	..	18	..	..	..	..

Scales were examined eight days after spraying but it was not possible then to be definite about their mortality.

The final examination was, therefore, postponed till 22 January 1937 when a similar piece of bark was removed from each tree and the number of living and dead scales counted. The two pieces removed for counting of the scales before and after spraying were from the same part of the branch and it could safely be presumed that the intensity of attack and the condition of insects were similar in the particular region.

Number of living and dead scales per sq. inch after spraying

Tree No.	I Kerosene oil emulsion	II Fish oil rosin soap	III Soft soap	IV Caustic soda	V Lime sulphur	VI Control
Living	276	1	..	62	21	516
Dead	217	175	360	340	624	18

The results were analysed by means of x^2. The percentage of mortality due to different treatments is given in Table III. The experiment was repeated in 1937 and 1938 with the difference that in 1938 six pieces of bark instead of one were examined. The average percentage mortalities under different treatments in 1937 and 1938 are also recorded in Table III.

TABLE III

The average percentage of mortality of the scale insect under different treatments during 1936-1938

Year of observation	Fish oil rosin soap	Soft soap	Lime sulphur	Caustic soda wash	Kerosene oil emulsion	Control
1936 .	99·3±0·78	100±1	96·7±0·67	84·6±1·78	44·0±2·3	3·3±0·74
1937 .	80·0±1·3	98·8±0·47	100·0±0	49·3±1·85	27·6±2·2	12·4±1·1
1938 .	89·87±0·47	97·6±0·68	97·8±0·28	65·9±0·6	28·52±0·62	8·86±0·41
Average for three years	89·72	98·8	98·2	66·6	33·37	8·19

It is definitely indicated by Table III that limesulphur and soft soap are most effective insecticides for the control of this pest. Fish-oil rosin soap, though not so effective, is significantly better than caustic soda wash and kerosene oil emulsion.

In the fourth year (1939), the three most effective insecticides were tried against grown up females, some of which had already oviposited. The average percentage mortality of the females due to lime-sulphur and soft soap was 98·86 and 89·6 respectively but fish-oil-rosin soap was found to be altogether ineffective. Lime-sulphur spray killed most of the eggs also.

Conclusion. From a perusal of the results of four years spraying trials, it would appear that almost cent per cent mortality can be obtained if the infested peach trees are sprayed with lime-sulphur or soft soap during winter at a time when the insects are young. Fish-oil-rosin soap is also very effective but the effect produced is not the same every time. Lime-sulphur is effective against grown up scales and their eggs also.

SUMMARY

Pseudaulacaspis pentagona (Targioni) is a very serious pest of peach trees in certain areas of Kumaun. The species is widely distributed in many peach growing countries of the world and is known to thrive upon a great variety of plants. The life history varies in different countries and on different hosts. In Kumaun some peach varieties have been observed to be very resistant to the pest.

Adults of both sexes and their immature stages have been described. A detailed account of life-history, as observed on peach trees in Kumaun, and the habits of the immature stages is given. In Kumaun hills, there are four broods in the year, but there is no resting period though the growth during winter is comparatively very slow, the winter brood occupying about five months.

After coming out from beneath the mother scale the larva remains active for over 24 hours in search of a suitable place to settle down and some such larvae can be found moving about on branches during the whole of the hatching period. During this period the pest can spread to great distances through the agency of birds and other animals including insects, human beings and wind. The chief source of its dispersal to long distances is, however, through the import of infested plants and other living plant material.

The insect can be kept off from an orchard situated on an isolated spot by not importing peach trees from areas known to be infested with it and by treating the imported material with lime-sulphur or soft soap to ensure the death of all young insects on it. The insect should be completely destroyed on its first appearance in any orchard by burning the affected parts. In orchards where the pest has established itself for quite a long time, a thorough spraying of all the infested trees with lime-sulphur or soft soap during winter should be carried out. For new plantations, only the varieties known to be highly resistant to the pest should, if possible, be selected.

ACKNOWLEDGEMENTS

The work was carried out at the Government Fruit Research Station, Chaubattia, United Provinces, with the financial assistance of the Imperial Council of Agricultural Research. The writer's thanks are due to Dr K. B. Lal, Entomologist to the Government of the United Provinces, for his guidance for the most part of the investigation and for going through the manuscript of this paper.

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ABSTRACT

A sample survey of after-effects of the Bengal Famine of 1943. P. C. MAHALANOBIS, RAMKRISHNA MUKHERJEAE, and AMBIKA GHOSH (1946). *Sankhya : Indian Journal of Statistics* **7** (4)

BENGAL was seriously affected by a famine in 1943. Material relating to the economic life of the rural population was meagre, and reliable information relating to the famine was simply not available. A sample survey was conducted in 1944-45 by the Indian Statistical Institute under the guidance of P. C. Mahalanobis in collaboration with K. P. Chattopadhyay, Head of the Department of Anthropology, Calcutta University, to investigate the after-effects of the famine.

2. Originally it had been intended to carry out the field survey with the help of University and College students during the summer vacation of May, June and July, 1944. In order to enable the work being done on an adequate scale the Government of Bengal were approached for financial assistance and grant-in-aid of Rs. 25,000 was sanctioned. There was, however, a delay of two months in sanctioning the grant which completely upset the time programme, and the field survey had to be extended from the end of July, 1944, to early February, 1945. Owing to the setting in of rains and other difficulties, expenses had increased very considerably. The field survey had therefore to be curtailed to some extent for lack of funds, and the analysis of the material was delayed for same reason.

3. The present report gives certain results based on a statistical analysis of a portion of the data collected during the enquiry but much material still remains unanalysed. Besides the after-effects of the famine the present survey has supplied valuable information relating to economic conditions in rural Bengal.

4. *Occupational groups.* The effect of the famine can be fully appreciated only when considered separately for different socio-economic sectors of the population. In the present report the family is the unit of survey and consists of all persons taking food from the same kitchen (in accordance with the census definition). Family occupation has been defined as that particular occupation from which the greater part of the total family income is derived.

5. Agricultural occupations have been sub-divided into four classes : 'agriculture' consisting of ryots (peasant proprietors) who actually cultivate their own land or land taken on share (*barga*) basis but who do not work as hired labourers : 'agriculture and labour' who not only cultivate their own land or land taken and on a share basis but also work as agricultural labourers : 'agricultural labour' consists of persons who do not own any land or only a negligible area : and 'non cultivating owner' is a heterogeneous group consisting of owners of large areas as well as widows and invalids who are obliged to cultivate their own land by hired labourers or on a share basis.

6. *Economic background of the famine.* The number of families in rural Bengal (in 86 sub-divisions covering about 70,000 square miles) in 1943 is estimated at 102·4 lakhs (10·2 millions) consisting of about 552 lakhs (55·2 millions) of persons with an average family size of 5·4 persons. The official figure for the total area under cultivation in normal times is about 250 lakhs (25 millions) of acre including double (or sometimes triple) cropped areas. (There are, however, reasons to believe that the actual area under cultivation is appreciably larger than the official figure.) Paddy forms the staple food and money crop of the province and constitutes about 88 per cent of the cultivated area. The area under *aman* paddy (the major winter crop) was probably something like 180 or 190 lakhs of acre just before the famine.

7. The average yield in round figures is about 10 maunds (about 820 lb.) of rice (not in husk) per acre. The average size of the family, defined as persons having food from the same kitchen

(in accordance with census practice), is about 5·4 in rural areas ; and the average over-all consumption of rice is estimated at about four maunds per head per year. The subsistence level is usually taken as two acres of paddy land per family on an average.

8. The actual position in Bengal even before the famine was precarious. About one-third of all rural families did not own any paddy land while two-fifths had less than two acres so that about three-fourths of all families had either no paddy land or owned less than two acres. The over-all average for the province as a whole was about 1·8 acre of paddy land per rural family which was below the subsistence level or on the border line. It is also worth mentioning that, averaged over a number of years before the war, there was a small but net import of about one per cent of total production of rice and other cereals into the province.

9. The cattle position also was not satisfactory. The simple survey showed that the total number of plough cattle in 1943 was 79 lakhs giving a share of $4\frac{1}{2}$ acres of paddy land per pair of bullock which according to many economists was only just adequate or fell slightly short of requirements.

10. In a majority of sub-divisions (25 out of 41 surveyed) more than 70 per cent of the families owned less than two acres of paddy land per family, and the average owned per family was something between 1·5 and 2 acres. In fact, classification of sub-divisions by amount of paddy land owned per family before the famine was found to be roughly parallel to the degree of incidence of famine conditions. This is, of course, just what is to be expected. Sub-divisions in which there were more families with paddy land below subsistence level were naturally more vulnerable to the famine.

11. *Land sale and mortgage.* During the period April, 1943 to April, 1944, 9·2 lakhs of families sold their paddy land in full or in part out of whom 2·6 lakhs had sold their land in full and had lost their only or chief means of livelihood ; 6·7 lakhs of families mortgaged their paddy land. In other words, nearly 15 lakhs of families (about one-fourth of the number who had owned paddy land before the famine) had either sold in full or in part or mortgaged their paddy land during the famine period.

12. Sales in full were most important in the group owing less than two acres ; 2·4 out of 40 lakhs or 6·1 per cent of families were obliged to do this and lost their chief means of livelihood. Only about 20,000 out of 16·2 lakhs or 1·2 per cent of families in the middle group (owning from two to five acres) sold all their paddy land : and less than 4,000 or 0·4 per cent out of 8·8 lakhs of families in the upper group did the same thing.

13. Sales in part were least frequent (about three out of 40 lakhs or 7·4 per cent) of families in the lowest group owning less than two acres ; most frequent (2·5 out of 16·2 lakhs or 15·3 per cent) in the middle group owning from two to five acres ; and quite frequent (1·1 out of 8·8 lakhs or 12·5 per cent) of families in the upper group owning above five acres of paddy land. Families in the lowest stratum who sold paddy land were obliged to do so in full rather than in part. In the upper group sales were most probably due to the very high price of paddy land which was a characteristic feature during the famine year. In the middle group, sales were probably due either to distress or to the desire to make profit depending on the economic position of the family.

14. The position may also be considered by occupational groups. Mortgage or selling paddy land in part was heaviest (7·2 per cent and 9·9 per cent respectively), but sales in full were comparativly low (2·4 per cent) in the group 'agriculture' indicating that there was general impoverishment but no pauperization on a large scale among cultivators owning their own land. The group 'agriculture and labour' was much more severely affected (6·0 per cent sales in full, 7·7 per cent of sales in part and 7·6 per cent of mortgage) showing that not only impoverishment but pauperization was widespread in this sector. The number of families in the group 'non-cultivating owner' is small, only 5·9 per cent of the total ; the majority is well off so that the proportion of families selling or mortgaging paddy land was low. The groups 'agricultural labour' and 'others' had little of paddy land and naturally did not participate much in sales or mortgage.

15. Considering the position by geographical regions it is seen that sub-divisions in which families owned, on an average, less paddy land were more severely affected by the famine. Families owning less land were obliged to sell it more heavily which increased further the number in the lower economic levels. Mortgaging was also comparatively heavy among less favourably placed families.

16. The most important point to note is that, during the famine, 2·6 lakhs of families (out of 65 lakhs owning paddy land) had totally lost their holdings and were thus reduced to the rank of landless labour. The famine transferred an appreciable number of families from the group 'agriculture' to 'agriculture and labour' and from 'agriculture and labour' to 'agricultural labour' and thus accentuated inequalities in the distribution of paddy land in the province.

17. Another fact is worth noting. Out of the total of 7·1 lakhs of acres of paddy land sold during the famine, only 2·9 lakhs of acre had been purchased back in the villages. Roughly 4·2 lakhs of acres of paddy land had thus passed to outsiders, possibly 'non-cultivating owner' residing in urban areas. In agriculture and 'non-cultivating owner' and 'others' groups of families roughly half the land sold had been purchased back. But among 'agriculture and labour' and 'agricultural labour' only about 10 per cent of the land sold have been replaced by purchase showing that net loss of paddy land was most severe in these two classes.

18. *Loss of plough cattle.* As already noted, the total number of plough cattle of Bengal before the famine was just adequate or fell short of requirements for the cultivation of *aman* paddy, the main crop of the province. The net loss of plough cattle was about 10 or 11 lakhs (about 13 per cent) during the famine period which must seriously affect agricultural operations in future. Out of this, 9·4 lakhs (65 per cent) were lost by sale, and 5 lakhs (or 35 per cent) of cattle by death. Only about one-fourth of the loss (3·5 lakhs) was replaced by purchase. About 3 lakhs or 8·5 per cent of familes of rural Bengal had probably lost all the cattle they had before the famine making it difficult or practically impossible for them to carry on normal agricultural operations.

19. Sales of cattle largely exceeded purchases showing that transfers had taken place not merely from one rural family to another, but that large purchases had been made by outsiders (possibly by contractors for the supply of meat for army consumption).

20. The average number of plough cattle owned per family naturally decreased in all groups but the reduction was largest in 'agriculture' and 'agriculture and labour', the two groups mainly concerned with cultivation. Even before the famine a considerable number of these families did not own any cattle; their number increased during the famine and further aggravated the cattle position.

21. *Economic deterioration.* It is possible to get some idea of economic deterioration by the number of families transferred from occupations at a higher economic level to occupations at a lower level. Assessed by such methods, it was found that about seven lakhs of families in rural Bengal had suffered a lowering of economic status with consequent decrease of earning power during the famine; adopting 5·4 as the average size of the family the total number of persons whose economic position had deteriorated was thus about 38 lakhs. It must be remembered that in this method deterioration within each occupational group has been ignored, that is, families retaining their occupational classification have not been taken into consideration.

22. In actual numbers, heaviest deterioration had occurred among families which originally belonged to the two occupational groups 'agriculture' and 'agriculture and labour' followed closely by rural 'trade' and 'craft'. Impoverishment had been, however, proportionately greatest among families following rural 'trade' and village 'crafts'.

23. *Destitution.* The rate of destitution (that is, proportion of persons living on charity) was 1·07 per cent at the time of the 1931 Census; the corresponding figure for 1941 is not available as relevant tables were not prepared. Assuming that the rate had remained steady, the total number of destitutes (on the basis of rural population of 55·2 millions) would have been about 5·9 lakhs in January, 1943. The sample estimate was about 7·5 lakhs so that at the beginning of 1943 there had been already an increase of 1·6 lakhs of destitute persons. There was a further increase of about 3·3 lakhs of destitutes between January, 1943 and May, 1944. At the normal rate of 1·07 per cent the total number of destitute families in May, 1944, should have been 6·0 lakhs. The sample estimates was 10·8 lakhs showing that 4·8 lakhs of persons had been rendered destitutes under war and famine conditions in Bengal.

24. Compared to the number of destitutes in January 1943 the largest proportion had come during the famine period from younger age groups. The proportion of destitute women was greater than destitute men especially among adults belonging to the age group 15 to 50 years which created a serious socio-economic problem.

25. In actual numbers, 'agricultural labour' (that is, landless labour) had contributed the largest share of destitutes during the famine; other groups in order of importance were 'agriculture', 'agriculture and labour', 'craft', 'fishing' and 'trade'; least affected were 'transport', 'non-cultivating owner' and 'husking paddy'. Proportionately to their total numbers most seriously affected were 'fishing', then 'agricultural labour', 'craft' and 'husking paddy'.

26. The chief cause of destitution was death of earners, next in importance was sickness or unemployment of earners.

27. It is worth noting that economic deterioration and destitution had affected different occupational groups in different ways. Economic deterioration was more important than destitution among the groups 'agriculture', 'agriculture and labour', while the reverse was the case among 'agricultural labour' and 'others'. Among 'others' again, economic deterioration was relatively more important in rural 'trade', 'transport', 'non-agricultural labour', 'profession and service', and 'craft' while destitution was relatively more important in the groups 'husking paddy' and 'fishing'. Among 'non-cultivating owner' both factors were comparatively small. Evidently occupational groups which could live on their assets were able to resist destitution to some extent but groups in more precarious position had succumbed more quickly to famine conditions.

28. *Deteriorating conditions before the famine.* Even in the pre-famine period (January, 1939 to January, 1943) the proportion of families suffering economic deterioration and destitution was much higher than the proportion who had improved their position. About 6·84 per cent of families had suffered economic deterioration against 3·32 per cent who had improved their economic level while the position of 1·07 per cent was not clear. This shows conclusively that economic deterioration had set in definitely in the pre-famine period and that the famine itself was its culmination.

29. *Accelerated changes during the famine.* During the famine period, rates of change became more rapid. Improvement during the famine period was relatively twice as great as that in the pre-famine period; but this was set off by a three times greater rate of economic deterioration and 12 times greater rate of destitution. The famine period was thus one of accelerated economic changes. Improvement of economic conditions was also quicker but was restricted to a comparatively small number of families. Deterioration and destitution were even more violently accelerated and were shared by a much larger number of families. Roughly 85 per cent of families, however, succeeded in maintaining their *status quo* showing that a large degree of economic inertia persisted even under famine conditions.

30. *General review.* The general picture is thus clear. Certain areas were very seriously affected others to a moderate extent; and still others only to a slight extent. This patchy nature of the incidence of famine conditions indicates that large regional differences in economic conditions had existed even in normal times, and were further accentuated during the famine. The poorer sections of the community, especially landless labour, fishermen and village craftsmen, were most severely affected and many were rendered destitutes; the middle groups who had land of their own and other assets were naturally less vulnerable while the upper stratum remained immune and sometimes even prospered. There is clear evidence to show that economic deterioration on the whole had set in even in the pre-famine period; a comparatively small number of families were improving their economic position while a far larger number were suffering from economic deterioration or destitution. During the famine period (January, 1943 to May, 1944) the whole process was greatly accelerated but the general nature of changes remained much the same. A small number of families improved their position while a much larger number were impoverished or rendered destitute. The famine of 1943 was thus not an accident like an earthquake but the culmination of economic changes which were going on even in normal times.

PLANT QUARANTINE NOTIFICATION

FOREIGN COUNTRIES

Summary of Quarantine Import Restrictions of Jamaica, British West Indies issued by United States Department of Agriculture

Commodity affected	Degree of prohibition on import	Date of promulgation or order
1. Citrus Crates	Total	18th December 1939
2. Citrus plants, buds or grafts . .	do.	18th June 1925 and 5th December 1933
3.(a) Coffee beans, grounds roasted or unroasted	do.	18th December 1941
4.(b) Roasted coffee	Allowed under permit by Collector General	do.
5. Copra	Total	Law 34 of 15 August 1939
6. Cornmeal	do.	15th August 1939
7. Earth or soil	do.	3rd April 1917
8. Bees and honey or beekeepers stock .	Allowed under permit by Director of Agriculture	12th March 1942
9. Citrus fruits, fresh or dried except its products	Total	21st August 1941 and 11th August, 1942
10. Coconuts unhusked	Allowed under permit by Director of Agriculture	May 1945
11. Cotton or any part of cotton or cotton seed	Allowed under permit by Director of Agriculture	....
12. Fodder and litter	Allowed under Health Certificate against Hoof and Mouth Diseases	19th September 1942, Amendment 29th January 1943, 8th February 1943, 3rd April 1943
13. Fruit and vegetables, except dried fruits and vegetables and onions	Total	13th January 1943. Amendment 22nd January 1936
14. Plants and tools	Allowed under permit by Director of Agriculture and at Kingston Port only	4th June 1929. Amendment 22nd January 1936
15. Seed potatoes	Total	10th February 1939
16. Sissal fibre	Allowed under permit from Collector General	21st August 1941

Further information can be had on application to the Plant Protection Adviser to the Government of India, Department of Agriculture, New Delhi

MGIPC—M—III-1-11—30-8-47—600.

Instructions to Authors

Articles intended for THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE should be accompanied by short popular abstracts of about 300 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged alphabetically according to author's names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets, when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state 'Original not seen'.

Sources of information should be specifically acknowledged.

As the forma of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{8}$ in. $\times$ $9\frac{5}{8}$ in. cut), no text-figure, when printed, should exceed $4\frac{1}{2}$ in. $\times$ 5 in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{3}{4}$ in. $\times$ 8 in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Imperial Council of Agricultural Research, New Delhi.